SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Oxygen Consumed and B.O.D.—Moore and Ruchhoft

1950 Industrial Wastes Forum

New York City Industrial Wastes Survey—Shapiro

Port Gardner Bay Pollution—Eldridge and Orlob

Important Priorities Notice—See Page 738

JUNE, 1951—VOL. 23, No. 6

Make Plans to Attend

TWENTY-FOURTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

CENTRAL STATES SEWAGE WORKS ASSOCIATION

MUNICIPAL AUDITORIUM

ST. PAUL, MINN.

October 8-11, 1951

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

Specify CHICAGO "PAKAGE" PLANTS

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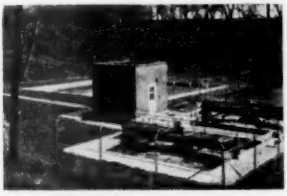
Spring Hill, La.

• FOR INDUSTRIAL PLANTS
Goodyear Tire & Rubber Co., Topeka, Kan.



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Chicago "Pakage" Plants were a major departure from conventional design when they were first introduced in 1934. They were built specifically to meet the needs of small communities, industrial plants and institutions. They can be operated by men without previous sewage experience. Since 1934, 200 Chicago "Pakage" Plants have been installed. All have excellent records for performance. None have failed.

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Ingenious automatic features of Chicago "Pakage" Plants simplify operation and assure successful performance. Former farmers, salesmen, coal-miners and truck-drivers—without previous experience—are operating existing plants. Operator training service by Chicago Operating Sanitary Engineers is provided with each plant.

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SEWAGE EQUIPMENT DIVISION

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Flush Kleen. Scru-Feller. Plunger. Horizontal and Vertical Non-Clogs Water Seal Pumping Units. Samplers.

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SEWAGE AND INDUSTRIAL WASTES

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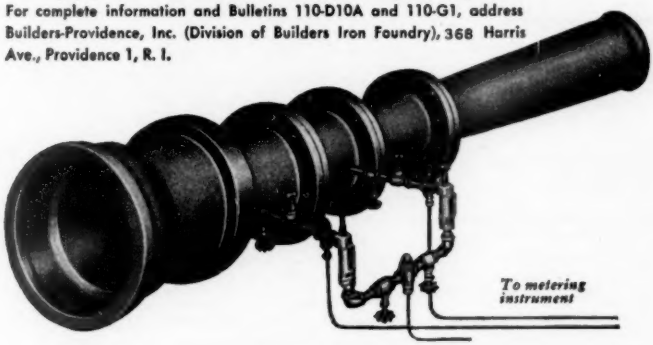

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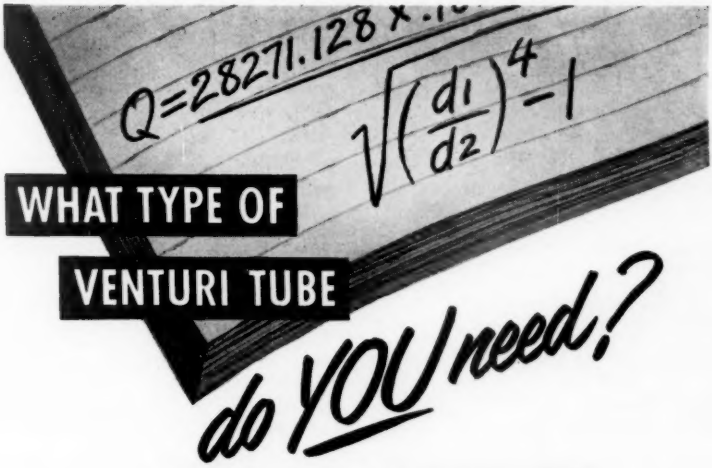
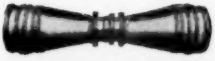


WHAT TYPE OF VENTURI TUBE do YOU need?

1. Steel plate tube with cast iron throat section for measurement of clear water, air or gases.



2. Cast iron Venturi Tube with hand holes and cleaning valves at main and throat sections, for municipal sewage and trade wastes.

3. Cast iron Venturi Tube with flat invert and single cleaning valve at main and throat sections. Specifically used for sludge.

4. Cast steel or cast iron Venturi for hot or cold water and adaptable for boiler feed high pressure service.

IT'S SIMPLEX
IT'S ACCURATE

SIMPLEX makes Venturi Tubes for measuring cold water, raw sewage, trade waste, sludge, process liquor, boiler feed, air and gases.

These tubes come in many sizes and different designs, some of which are pictured above. This means there's a particular tube to fit specific needs.

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SIMPLEX
VALVE AND METER COMPANY

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Association	*Place*	*Time*
Alabama Water and Sewage Association	University of Ala., Tuscaloosa, Ala.	June 15, 1951
Institute of Sewage Purification	Buxton, England	June 18–22, 1951
Ohio Sewage and Industrial Wastes Treatment Conference	Neil House, Columbus, Ohio	June 20–21, 1951
Canadian Institute on Sewage and Sanitation	Royal York Hotel, Toronto, Ont.	Aug. 20–22, 1951
Pennsylvania Sewage and Industrial Wastes Association	State College, Pa.	Aug. 22–24, 1951
Iowa Sewage Works Association	Hotel Tall Corn, Marshalltown, Iowa	Sept. 11–13, 1951
Kentucky–Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Georgia Water and Sewage Association	Georgia Institute of Technology, Atlanta, Ga.	Sept. 19–21, 1951
South Dakota Water and Sewage Works Conference	Charles Gurney Hotel, Yankton, S. Dak.	Sept. 19–21, 1951
Rocky Mountain Sewage Works Association	Cosmopolitan Hotel, Denver, Colo.	Sept. 26, 1951
North Dakota Water and Sewage Works Conference	Gardner Hotel, Fargo, N. Dak.	Sept. 26–28, 1951
Missouri Water and Sewerage Conference	Robidoux Hotel, St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
West Virginia Sewage and Industrial Wastes Association	Daniel Boone Hotel, Charleston, W. Va.	Oct. 3–4, 1951

Federation of Sewage and Industrial Wastes Associations
in conjunction with Central States Sewage Works Assn.
Municipal Auditorium, St. Paul, Minn.
October 8–11, 1951

Florida Sewage and Industrial Wastes Association	The Princess Issena Hotel, Daytona Beach, Fla.	Oct. 28–31, 1951
New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951
Oklahoma Water, Sewage and Industrial Waste Conference	Oklahoma A. & M., Stillwater, Okla.	Dec. 10–14, 1951

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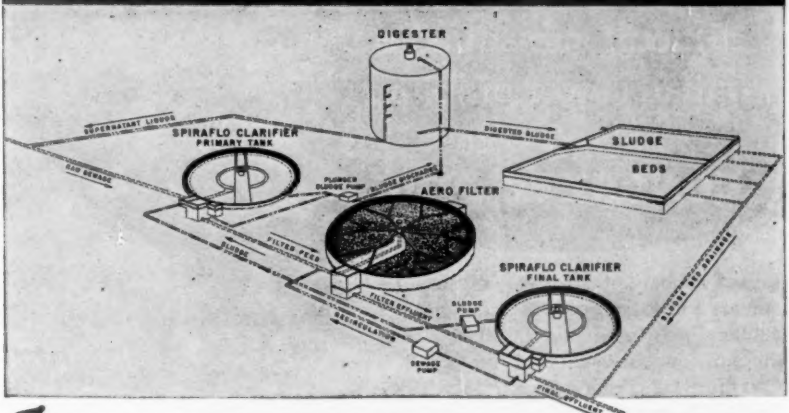

THIS LOW RATE, HIGH CAPACITY TRICKLING FILTER PLANT IS ESTABLISHING AMAZING RECORDS FOR HIGH PURIFICATION AT EXCEPTIONALLY LOW COST

These figures show a typical result produced by a Yeomans installation of the "Aero-Filter" and "Spiraflo" Clarifier in combination.

Overall plant efficiency is always higher when these units are used together. The method is especially effective for treating strong industrial wastes.

OPERATIONAL DATA . . . SPIRAFLO—AERO-FILTER PLANT *

1949 Date	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids PPM	Per Cent Reduction	Per Cent PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	253	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant furnished on request, as well as operating data from other installations.

"Spiraflo" Advantages

- Increased B.O.D. and settleable solids removal —influent is introduced tangentially into annular race around the periphery. Sewage spirals downward slowly and enters main clarification compartment at the bottom of the tank. Uniform, slow diffusion of waste under the skirt results in greatly reduced velocities and provides maximum removal of settleable solids.
- Greater removal of finely divided particles—due to upward flow through sludge blanket. This increases flocculation and results in more effective removal of finely divided particles before waste enters the effluent weirs.
- Straight-wall design minimizes construction costs.

"Aero-Filter" Advantages

- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary
- Operating cost is lowest of any type of complete sewage treatment
- Uninterrupted and almost complete momentary bed coverage minimizes troubles from odors, freezing, ponding, filter flies
- All returns made direct to the filter—no oversize primary tank required.

FOR INDUSTRIAL WASTES, TOO . . . Many types of industrial wastes can be successfully treated by direct application to the Aero-Filter without preliminary sedimentation.

Bulletins containing full details and helpful engineering data will be sent promptly upon request

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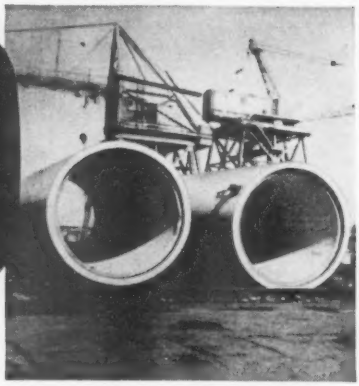
Oakland's difficult sub-aqueous outfall sewer problem solved with **CONCRETE PIPE**

Buried beneath 40 feet of water near the famous San Francisco-Oakland Bridge is another great engineering achievement, the sub-aqueous section of the outfall of Oakland's East Bay Municipal Utility District. It consists of 5,970 ft. of 96-in. reinforced concrete pipe. This pipe was cast in 24-ft. lengths with walls 9 in. thick, each length weighing 39 tons.

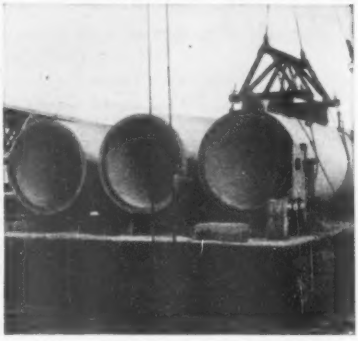
In placing this outfall the engineers faced many difficulties—excavating bay bottom mud deposits ranging from 7 to 40 feet deep, working in water at temperatures of 50 to 55 degrees, heavy tides, placing and aligning the pipe with divers and conducting backfilling operations under water.

This is another example of how concrete pipe can solve difficult or unusual sewer problems. In thousands of installations over scores of years, concrete pipe has demonstrated its rugged durability, great structural strength, maximum hydraulic capacity, minimum infiltration and leakage, resistance to wear by abrasive matter.

Concrete pipe is moderate in first cost, requires little or no maintenance and gives many years of service. The result is a ***low-annual-cost*** sewer installation.



Two 24-ft. sections of 96-in. reinforced concrete sewer pipe on loading dock at Oakland.



Preparing to lift a 24-ft. section of concrete pipe from pipe barge over the line in the bay.

Concrete pipe being lowered in place. Note redwood chocks.

AMERICAN CONCRETE PIPE ASSOCIATION

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ACCELO® FILTER

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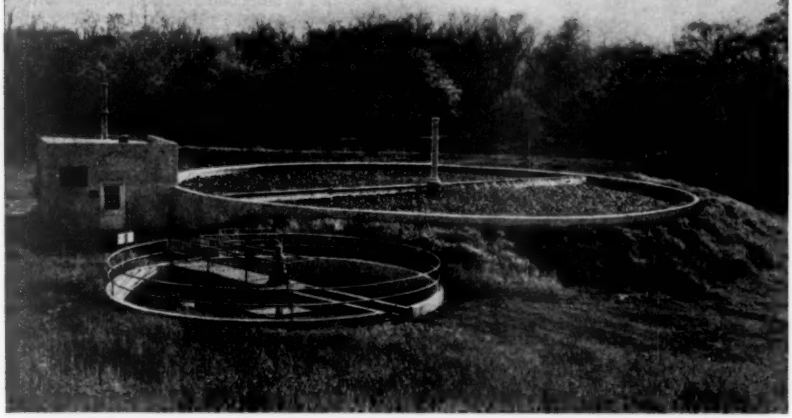

ACCELO FILTER INSTALLATION AT WHITEHALL, ILLINOIS

Direct Recirculation can be easily Included in any Treatment Plant!

Biological oxidation is greatly accelerated by the Accelo Filter in the treatment of sewage and other organic wastes. This is accomplished by recirculating large quantities of the fresh unsettled trickling filter effluent directly back to the inlet of the filter distribution equipment. This method of operation eliminates many of the nuisances common to the conventional trickling filter. The ACCELO FILTER System may be used to give increased capacity to overloaded conventional trickling filters as it makes higher dosing rates possible. Other advantages include: 1. Increased biological filter efficiency, 2. No increase in size of sedimentation tanks, 3. Smaller trickling filters, 4. No clogging, sloughing or ponding, 5. No odors, 6. Reduction of psychoda fly nuisance.

WRITE FOR *complete information concerning the ACCELO FILTER SYSTEM. Ask for 12-page catalog No. 6200 containing flow diagrams, charts, installation diagrams, pictures, and interesting descriptions of its many superior advantages.*

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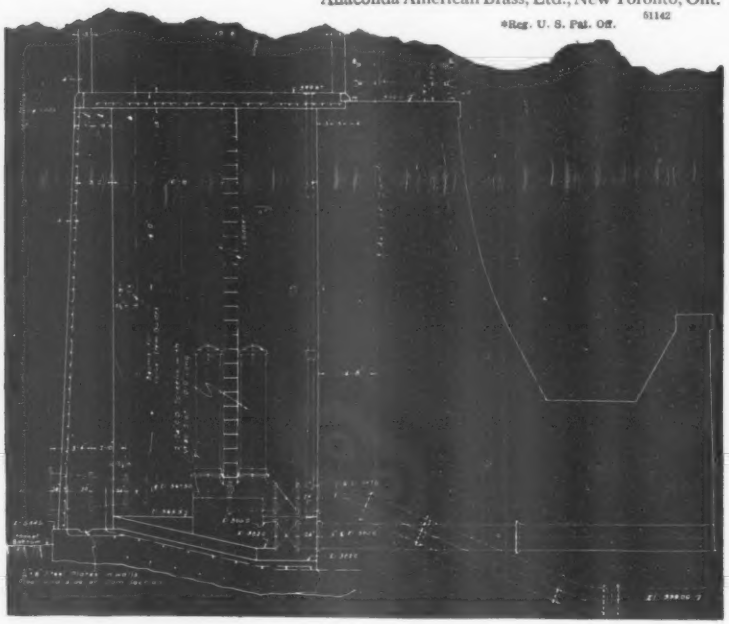

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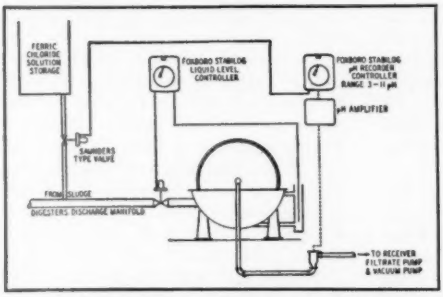
Vacuum filtration unit at Hyperion Activated Sludge Plant, showing instrument panel for pH and liquid level controllers.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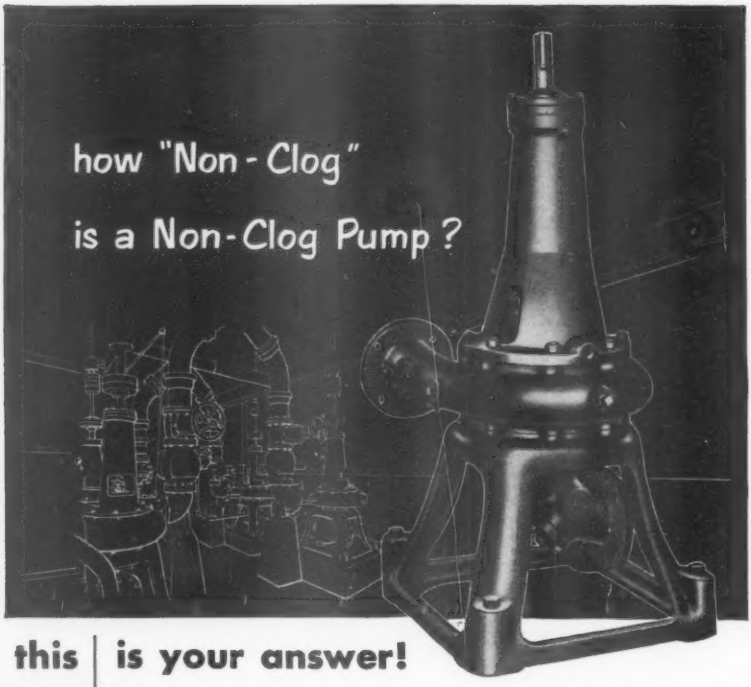

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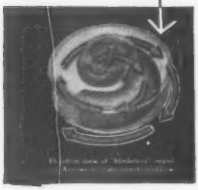

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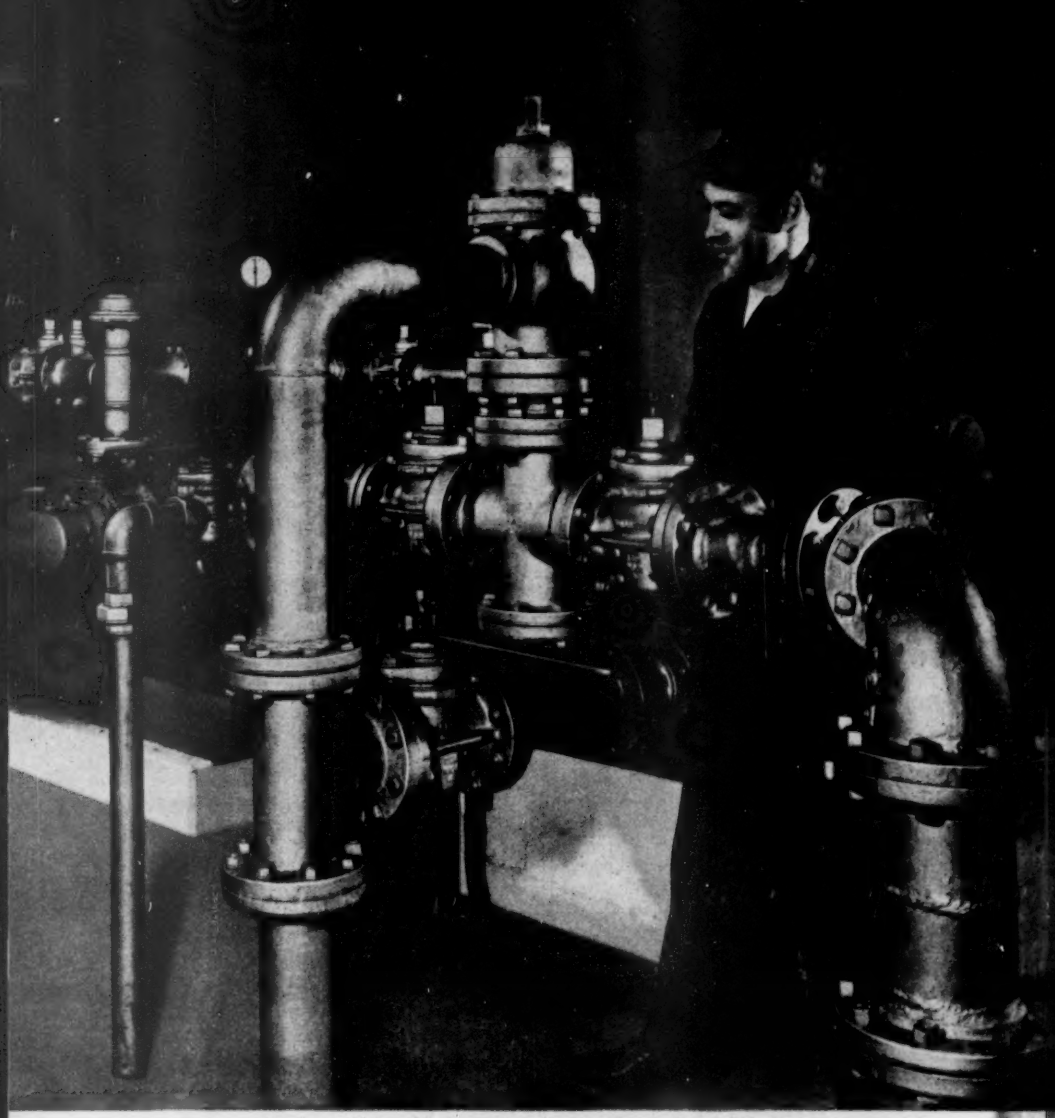

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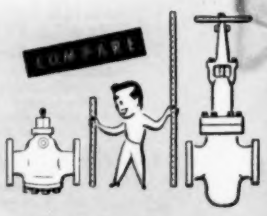

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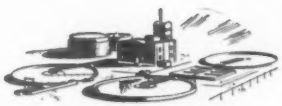

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LINK-BELT combines bar screen and grit chamber in one economical unit

OVER 70 small and medium size treatment plants enjoy the savings provided by the Link-Belt Tritor Screen.

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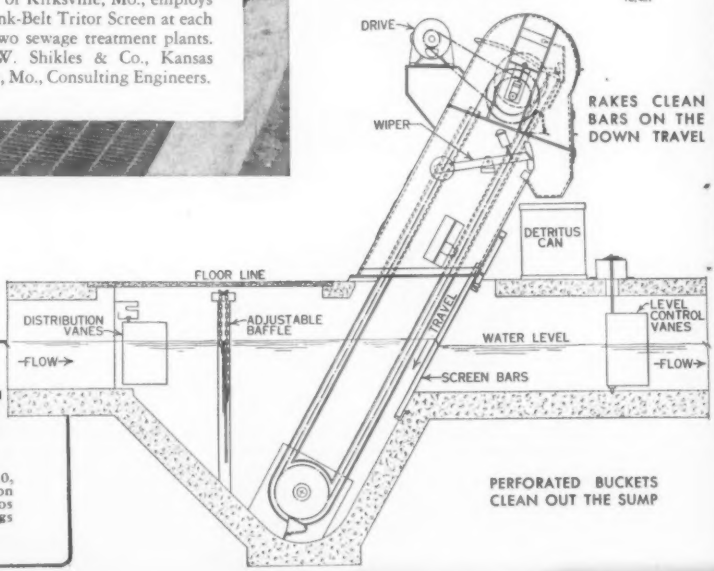
For details on Tritor Screens and other equipment in the broad Link-Belt line, call the office near you. A Link-Belt sanitary engineer will be glad to give you complete information.

12,427



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750,000 pounds of filter cake per day

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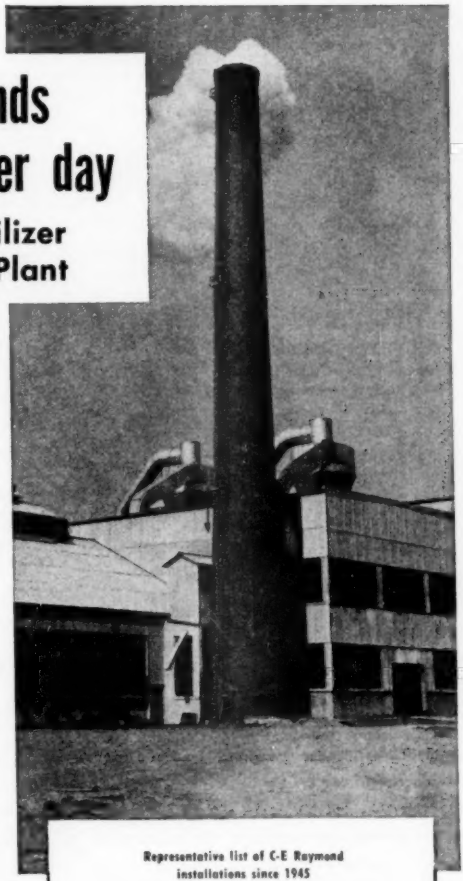

Another step in Houston's long range plans for complete waste treatment was finished last August with the opening of a C-E Raymond equipped, 28,000 tons per year municipal sewage sludge drying plant.

The two new Flash Drying Systems, located at Houston's North Side plant, dry activated-sludge from both the North Side and Sims Bayou plants. Most of the dried sludge is marketed locally for fertilizer but some is shipped as far as the East Coast.

This new plant, designed to serve an equivalent population of 775,000, is equipped with two C-E Raymond Flash Drying Units, each having an evaporation rate of 12,000 pounds per hour.

The Houston Plant is typical of C-E Raymond System installations, now in service in virtually all parts of the country, meeting the varying requirements of both large and small communities. They are flexible in layout, highly efficient and thoroughly reliable; they provide for maximum utilization of waste heat.

The services of C-E specialists are available to assist you in finding the best solution to *your* sludge disposal problem. Get in touch with the office nearest to you for prompt attention.

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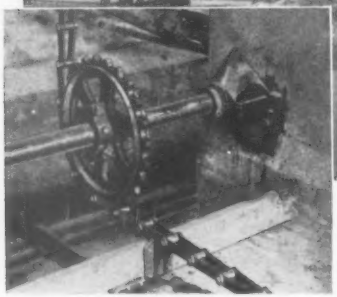

A "PERMALIFE" hunting tooth sprocket is shown in inset at left. Large view shows a group of Jeffrey Collectors all equipped with "PERMALIFE" Sprockets. Jeffrey FLOCTROLS on this job, also.

It's the SPROCKETS THAT MAKE THE DIFFERENCE

Jeffrey Sludge Collectors are different (and last longer) when equipped with our hunting tooth "PERMALIFE" Sprockets of unique design. The sprocket has an odd number of teeth (approximately 3" pitch)—one tooth moves forward at each revolution. Over any period of time the sprocket teeth get approximately one half the number of contacts with the chain barrels as in the case of regular 6" pitch sprockets.

This feature, together with Chainsaver Rims which support the side bars of the chain, WILL DOUBLE THE LIFE OF THE SPROCKETS. Investigate these IMPROVED Sprockets—made of alloy cast iron and chilled.

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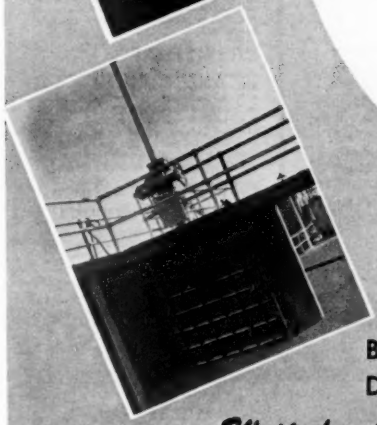

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Known strength factors! Proved resistance to corrosion! These are your only safe and sure guides to long life and low maintenance expense of water, gas and sewer mains laid under costly modern pavements. The four strength factors that pipe must have to survive traffic shocks, heavy external loads, beam stresses and severe working pressures are listed in the box opposite. *No pipe that is deficient in any of these strength factors should ever be laid in paved streets of cities, towns and villages.* Cast iron water and gas mains, laid over a century ago, are serving in the streets of 30 or more cities in North America. These attested service records prove that cast iron pipe not only assures you of effective resistance to corrosion but all the strength factors of long life and economy, as well.

In city streets lay pipe known for STRENGTH

CRUSHING STRENGTH

The ability of cast iron pipe to withstand external loads imposed by heavy fill and unusual traffic loads is proved by the Ring Compression Test. Standard 6-inch cast iron pipe withstands a crushing weight of more than 14,000 lbs. per foot.

BEAM STRENGTH

When cast iron pipe is subjected to beam stress caused by soil settlement, or disturbance of soil by other utilities, or resting on an obstruction, tests prove that standard 6-inch cast iron pipe in 10-foot span sustains a load of 15,000 lbs.

SHOCK STRENGTH

The toughness of cast iron pipe which enables it to withstand impact and traffic shocks, as well as the hazards in handling, is demonstrated by the Impact Test. While under hydrostatic pressure and the heavy blows from a 50 pound hammer, standard 6-inch cast iron pipe does not crack until the hammer is dropped 6 times on the same spot from progressively increased heights of 6 inches.

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In full length bursting tests standard 6-inch cast iron pipe withstands more than 2500 lbs. per square inch internal hydrostatic pressure, which proves ample ability to resist water-hammer or unusual working pressures.

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 **JUNE, 1951** **Number 6**

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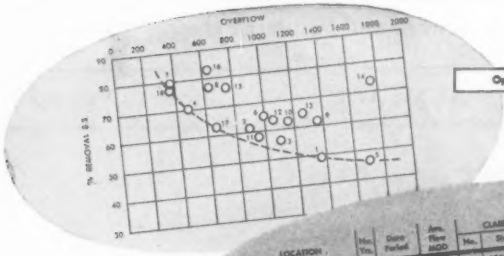

Operating Data on Dorr Sifeed Clarifiers—

radial flow—round or square units. Chart graphically illustrates results given in table below.

LOCATION	No. Yrs.	Date Period	Av. Flow MGD	CLARIFIERS No.	Size	W.D.	Det. Hrs.	Over-flow Gal.	SUSP. SOLIDS Raw	Eff.	% Rem.
Washington, Blue Plains Plt.	2	1944-45	136.3	12	104' Dia.	14	1.88	1350	165	83	49
Gary, Ind.	4	1941-44	20.11	4	75' Sq.	10	2.0	900	265	104	61
Winnipeg, Man.	2	1943-44	22.8	2	112' Dia.	12	1.98	1100	348	139	55
Battle Creek, Mich.	5	1938-42	4.92	3	80' Dia.	10	3.66	690	282	58	70
Buffalo, N. Y.	3	1939-41	132	4	160' "	15	1.6	1690	209	114	46
Albuquerque, N. M.	7	1939-46	5	1	80' "	12.2	2.21	990	254	91	64
Yakima, Wash.	1	1942	9.3	4	90' "	9	4.32	373	110	23	79
Appleton, Wis.	7	1938-45	4.8	2	70' "	10	2.90	625	276	63	77
Baltimore, Md.	4	1939-46	89.5	3	170' "	13	1.64	1360	214	83	61
Springfield, Ohio	4	1937-40	14.8	2	80' "	10	1.59	1160	166	65	65
Mansfield, Ohio	2	1944-45	9	1	65' "	12	2.28	905	208	87	58
Cedar Rapids, Ia.	9	1936-44	4.31	1	70' "	11.5	1.95	1040	364	132	63
Austin, Texas	2	1944-45	5.64	1	75' "	12	1.69	1275	263	93	64
Neenah-Menasha, Wis.	4	1942-45	7.93	2	75' "	10	1.0	1790	681	188	72
Denver, Colo.	5	1939-43	46	4	140' "	9.7	2.36	750	197	44	77
Sheboygan, Wis.	1	1944	6.4	2	80' "	10	2.6	633	242	60	82
Tuscaloosa, Ala.	3	1943-45	1.66	3	40' "	9	2.5	660	226	57	68
Hancock, Mich.	8	1938-46	4.3	2	80' "	7.9	2.38	578	229	73	77

check these facts ON DORR SIFEED CLARIFIER PERFORMANCE

A few moments' study of this graph and the supporting table will give you a clear idea of what kind of performance you can expect Dorr Clarifiers to deliver.

- ***These are long term records . . . obtained by competent plant chemists at well established installations. We believe they cannot be equaled.***
- ***Performance is one of the primary factors upon which Clarifier excellence should be judged. Are you getting the best?***

We'd like to give you some figures on Dorr Clarifier repair costs too. Ask a Dorr engineer for the facts.

**Sifeed is a trademark of The Dorr Company, Reg. U. S. Pat. Off.*

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Sewage Works

CHEMICAL OXYGEN CONSUMED AND ITS RELATIONSHIP TO B.O.D.*

By W. Allan Moore and C. C. Ruchhoft

Chemist and Sanitary Engineer Director, respectively, U.S.P.H.S., Environmental Health Center, Cincinnati, Ohio

The oxidation of organic compounds contained in sewage and polluted water has interested workers in the field of sanitary science for a number of decades. Frankland (1), in 1870, first proposed the forerunner of the modern biochemical oxygen demand (B.O.D.) test. He measured the decrease in the dissolved oxygen content of samples of water from the River Thames. However, his conception of the process taking place in such samples was radically different from that of later workers. He believed that it was purely a chemical oxidation by the oxygen dissolved in the water.

In 1884, Dupré (2) showed as a result of his research that the decrease in the dissolved oxygen content of incubated samples was caused by the metabolic activities of the organisms present. Thus, the modern concept of biochemical oxidation arose.

This concept has resulted in many research studies by various investigators during the past half century. Phelps (3) and Theriault (4) were among the first to propose the concept of an unvarying velocity constant, k, of 0.1. This constant has more or less been universally accepted in the fields of stream sanitation and sewage treatment until within the last few years. It was not until 1948 that Ruchhoft *et al.* (5)(6) and Gotaas (7) showed that although the course of biochemical oxidation followed the unimolecular formula, nevertheless, the velocity constant, k, might vary between the values of 0.07 to 0.25.

This variance of k has an important bearing on the correlation of the oxygen demand of polluted waters as determined biochemically to that as determined by strictly chemical means. It is because of this variance in the metabolic rates of the microbic population present that limited correlation can be expected between these two parameters. Another important factor that enters into consideration is the fact that chemical methods cannot distinguish between a biologically stable and unstable organic material. This is well illustrated in the case of the oxidation of cellulosic materials, which are present in raw sewage. Cellulose is one of the complex organic compounds that is oxidized quantitatively by chemical means and is not attacked biochemically under aerobic processes usually encountered in stream purification or sewage treatment. On the other hand, there may be present organic acids, which form a source of food for bacteria. These organic acids were not attacked by chemical oxidants commonly used. Recently it has been shown (8) that acid dichromate in the presence of a silver catalyst will oxidize these organic acids.

In spite of the fact that the oxygen consumed by chemical and biochemical methods does not necessarily agree,

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numerous attempts have been made to devise chemical methods that would give estimates of the biochemical oxygen requirements in shorter time periods than required biochemically. As pointed out previously, although limited correlation between these two parameters exist in most cases, each has its place in the field of stream sanitation and industrial waste and sewage treatment.

The biochemical oxygen demand determines the quantity of oxygen required for biochemical stabilization when a sewage or industrial waste is discharged into a surface water. This test is made under pH and temperature conditions that simulate the natural conditions present. The oxygen consumed test, on the other hand, is a measure of the chemical oxidant required to oxidize the organic matter under very special and unnatural conditions; that is, high acidities and temperatures.

In the case of many industrial wastes, there may be present toxic materials which inhibit the normal biochemical processes. Nevertheless, such a waste when discharged to a stream may exert a deleterious effect in various ways and a chemical oxygen consumed test may be used to estimate the concentration of such pollution. Inorganic wastes, such as those containing ferrous iron or sulfite, are best evaluated by means of the oxygen consumed test. This test may be valuable in determining the approximate strength of an unknown industrial waste and, thereby, an estimate of the range of dilutions needed for determining the B.O.D. can be ascertained in a minimum of time. Because a chemical method for determining oxygen consumed can give valuable information, it is desirable to review the various procedures that have been proposed.

Oxygen Consumed Methods

For years past the use of permanganate as an oxidizing agent has been accepted by Standard Methods (9). That those procedures using permanganate are not entirely satisfactory is well shown by some of the numerous modifications that have been proposed (10) (11) (12) (13) (14) (15) (16). Because of the variable results obtained with permanganate, other oxidizing agents have been used by various research workers. Of these, only potassium dichromate and iodic acid have been received favorably by sanitary chemists. Recently (8) a comparative study was made in the Environmental Health Center laboratory of the more promising methods that have been proposed. This study included the dichromate methods proposed by Madison (17), by Ingols and Murray (18), and by Moore, Kroner, and Ruchhoft (19). It had been shown by Muers (20) that silver sulfate could be used as an oxidation catalyst in conjunction with a dichromate method. Consequently, the use of silver sulfate was also studied in conjunction with the Moore method (19). The iodic acid method first proposed by Dzyadzio (21) and later modified by Johnson, Tsuchiya, and Halvorson (22), and the standard permanganate method (9) were also studied along with the dichromate methods.

A part of the results of this study carried out with four typical industrial wastes and four organic compounds is summarized in Table I. From the statistical comparison of the various methods, as given in Table I, and from other considerations, both the standard permanganate and the Madison procedures were eliminated as being unsatisfactory.

The data given in the last column of Table I are a measure of the precision of the various methods. For example, on the organic dye waste, it is shown that in 95 per cent of the cases a single determination with the iodate method will come within 11.5 per cent of the mean value. With the Moore method on this same waste, results can be expected such that 95 per cent of the time a single determination

TABLE I.—Statistical Comparison of Oxygen Consumed Methods

Compound or Waste	O.C. Method Used	Mean O.C. (p.p.m.)	Standard Deviation (p.p.m.)	100 C.L./$\bar{X}$[1]
Organic dye waste	Iodate	960	39.4	11.5
	Ingols	1,153	73.6	14.4
	Madison	690	211	67.5
	Permanganate	463	33.3	16.2
	Moore	1,183	15.9	3.0
Ortho-cresol	Iodate	575	14.0	6.8
	Ingols	543	12.9	5.3
	Madison	459	30.5	15.0
	Permanganate	443	22.8	11.7
	Moore	530	5.1	2.3
Oil refinery caustic waste	Iodate	50,900	2,274	12.4
	Ingols	46,000	874	4.3
	Madison	32,200	2,838	19.9
	Permanganate	29,100	1,232	9.6
	Moore	48,400	347	1.6
	Moore—Ag_2SO_4	57,500	742	2.9
Textile dye waste	Iodate	27,500	1,634	16.5
	Ingols	35,200	569	3.7
	Moore	36,600	204	1.3
	Moore—Ag_2SO_4	—	—	—
Glycocoll	Iodate	—	—	—
	Ingols	417	18.3	10.0
	Moore	592	4.5	1.7
	Moore—Ag_2SO_4	607	4.5	1.7
Distillery waste	Ingols	356	14.8	9.3
	Moore	344	6.0	4.0
	Moore—Ag_2SO_4	902	5.3	1.3

[1] A single determination will come within the stated percentage of the mean 95 per cent of the time.

will come within 3 per cent of the mean. Both the standard permanganate and Madison's methods are shown to be inferior to the other methods. On all subsequent samples both the Ingols and Moore procedures gave the best reproducibility, even though the former was slightly inferior to the iodate method on the organic dye waste.

When silver sulfate is used as a catalyst in conjunction with the regular Moore method the usefulness of the latter is extended in many cases. This is particularly true when a given waste contains aliphatic acids or alcohols. Such acids are not oxidized by the regular procedure, but are quantitatively broken down when silver sulfate is used as a catalyst.

There are other factors involved in the selection of a method for the determination of oxygen consumed besides the precision involved. For example, the time involved in running five samples and five blanks with the iodic acid method is 7 hr. 45 min. Of this time, 7 hr. are actually spent in manipulation. The same holds true for Madison's procedure. With both Madison's and Ingols' methods, the end points on the titration are hard to judge, which is one of the factors causing poor reproducibility. In addition, with these two methods the sample size that can be used is limited, which introduces additional errors, especially when strong wastes are being studied.

Although the permanganate method

TABLE II.—Effect of Silver Sulfate on Moore Oxygen Consumed Method

Compound[1]	Mean O.C. (p.p.m.)		Range of O.C. (p.p.m.)		Per Cent of Theory	
	Regular	With Ag_2SO_4	Regular	With Ag_2SO_4	Regular	With Ag_2SO_4
Acetic acid	26	1,014	38	62	2.4	95.1
Alanine	326	870	25	17	33.5	80.6
Furoic acid	1,074	1,254	57	14	83.6	97.6
o-cresol	2,095	2,413	54	43	83.2	95.8
Ethanol[2]	619	1,672	67	33	29.7	80.1
Benzene	240	250	18	28	7.8	8.1
Pyridine	34	20	6	17	1.3	0.8

[1] 10 replicates were run of each compound with and without the silver catalyst.
[2] 87 per cent C_2H_5OH.

requires less manipulation time than any of the other methods, it is quite difficult to obtain uniform results. Some of the replicates may boil more vigorously than others, thereby concentrating the solution and affecting the results. The effect of agitation on the sample is also noticeable, as manganese dioxide tends to precipitate, and if the sample is not agitated frequently, variable results will be obtained. In many cases the precipitated manganese dioxide is difficult to dissolve. Sample size is also important, for if more or less than 50 per cent of permanganate is used, variable results are obtained.

The Moore method is intermediate as far as time and manipulation are concerned. With this method, sample size is not as critical and the end point is quite sharp and reversible. The use of silver sulfate as a catalyst, previously mentioned, extends the usefulness of this method. Aliphatic acids and alcohols are oxidized quantitatively, as in the case of biological oxidation. This fact is well illustrated in the results shown in Table II.

Uses of Oxygen Consumed in Conjunction with B.O.D.

Sewage

In recent years many investigators have attempted to substitute oxygen consumed procedures for the standard B.O.D. test. However, as pointed out previously, this substitution is not justified in most cases, as the methods are two distinct parameters and must be considered as such.

Among the first workers to attempt a comparison between oxygen consumed and B.O.D. on sewage were Mohlman and Edwards (23) in 1931. Although the method used by these investigators, as well as that used by Burtle and Buswell (24), gave precise results, they were unable to correlate the two parameters satisfactorily.

Rhame (25), using an oxygen consumed method, later modified by both Madison (17) and Ingols (18), also attempted such a correlation. From his results he concluded that it was difficult to obtain reliable results, but thought that the difficulty lay in the oxygen consumed technique used. In a later study (26), he found that the results obtained with raw and settled sewage were radically different. In the case of the raw sewage the results were much more erratic than in settled sewage. However, in Rhame's determination of oxygen consumed he used an acid concentration much less than 50 per cent by volume. These factors of acid concentration and character of sewage are discussed later.

Ingols also attempted to correlate oxygen consumed with B.O.D. and in his study used raw and settled sewage as well as trickling filter effluent. He multiplied his oxygen consumed values by 0.68, which assumes a velocity con-

stant of 0.1. Even after such adjustment of the data, the oxygen consumed values obtained were still higher than the corresponding B.O.D. This is particularly true of the filter effluent, as might be expected. This higher O.C./B.O.D. ratio is due to the fact that the organic compounds remaining and those formed during biochemical oxidation are stable biochemically, but are still subject to chemical oxidation by a strong oxidant.

Table III gives some comparative data on oxygen consumed and the biochemical oxygen demand of domestic sewage containing no industrial waste of any kind. In connection with these data, two factors should be kept in mind. First, all sewage samples were filtered through cotton, thus removing any gross particles (including cellulosic material) present in the original sample. Secondly, the oxygen consumed of the sample was determined using 33 per cent by volume of sulfuric acid. These two factors have an important bearing on the oxygen consumed values obtained by the dichromate method and merit closer consideration.

As mentioned previously, cellulosic materials present in a sewage or industrial waste are oxidized quantitatively by chemical oxidants. They are not oxidized biochemically under aerobic conditions. By the removal, therefore, of such materials from a given substrate such as domestic sewage, one would expect a somewhat closer correlation between the oxygen consumed and B.O.D. values obtained. This has been found to be true by other investigators, as already mentioned, and is borne out by the data presented in Table III.

TABLE III.—Relation Between Oxygen Consumed [1] and 5-Day B.O.D. of Domestic Sewage[2]

Sample	Oxygen Consumed (p.p.m.)	5-Day B.O.D. (p.p.m.)	O.C./B.O.D.
1	187	200	0.94
2	347	340	1.02
3	329	338	0.97
4	162	156	1.04
5	263	261	1.01
6	294	301	0.98
7	230	241	0.95
8	205	145	1.41
9	151	149	1.01

[1] 33 per cent by volume of H_2SO_4 used in conjunction with the Moore method.
[2] Filtered through cotton.

The second factor mentioned above, namely the effect of acid concentration on the oxygen consumed value obtained, has also been studied before (19). The lower the acid concentration in the reflux mixture, the lower the oxygen consumed will be. This factor, no doubt, has a bearing on the results as shown in Table III.

It would be extremely difficult to set up the exact conditions in the oxygen consumed test that would duplicate B.O.D. values. Such duplication might be obtained in a given short series of samples, but as a rule the variables are such that constancy of the O.C./B.O.D. ratios cannot be expected in sewage samples.

Polluted Streams

A small stream (Lytle Creek) under study at the Environmental Health Center receives the effluent from a primary sewage treatment plant. This effluent comprises approximately 75 per cent of the stream flow. Table IV gives the ratio of the oxygen consumed to the 5-day B.O.D. in this stream. Consideration of the first point (Station 6), which is above the sewage effluent outfall, shows that biologically the stream is stable, but contains organic compounds, which are chemically oxidized. The effect of removing the gross particles by primary sedimentation is seen in the data for the sewage effluent. Here the ratio between the oxygen consumed and B.O.D. values is smaller. As one progresses down the stream a change in the O.C./B.O.D. ratio is seen. This, again, is simply an increase in the biologically stable ma-

TABLE IV.—Ratio of Oxygen Consumed to 5-Day B.O.D. on Stream Samples

Date	Station[1]							
	Above Effluent 6.0	Sewage Effluent	Below Effluent					
			5.8	5.1	4.0	3.0	2.2	0.3
Dec. 6, 1949	8.6	1.8	2.2	1.6	2.7	3.1	5.0	5.5
Mar. 14, 1950	6.5	3.3	3.3	—	—	—	4.0	4.6
Aug. 16, 1950	9.1	1.5	1.6	1.9	5.3	8.2	—	—
Sept. 29, 1950	20.2	1.6	1.3	1.8	4.1	—	8.7	8.2

[1] Miles from mouth of stream.

terial, which is readily oxidized chemically.

Another factor that is noticeable from the data presented in Table IV is the variation in the O.C./B.O.D. ratio for the same station at various periods of the year. The data show that it would be impossible to predict (even though the stream is receiving the same type of sewage throughout the year) what the B.O.D. would be at a given point from the results of one survey when the oxygen consumed alone is determined.

In Table V a comparison is given between the O.C./B.O.D. ratio at various stations on a river receiving the wastes from an oil refinery. These data again show that above the point of discharge the stream water has a high O.C./B.O.D. ratio, which indicates, again, that although biological stability and a low B.O.D. has been obtained the river contains considerable material capable of oxidation by chemical methods. It also is apparent that a large portion of the discharged effluent from the oil refinery is amenable to biological oxidation, as the oxygen consumed to 5-day B.O.D. ratio is much smaller.

TABLE V.—Ratio of Oxygen Consumed to 5-Day B.O.D. on Stream Polluted by Oil Refinery Waste

Station	O.C./B.O.D.
Above plant effluent	7.8
Just below plant effluent	2.0
1,000 yd. below plant effl.	1.9

One of the difficulties encountered in applying oxygen consumed methods to polluted streams is the relatively small amount of oxidizing agent required to oxidize the organic material present. If, for example, one uses the same normality of dichromate in stream pollution surveys as is used for sewage or industrial wastes, the consumption of the oxidizing solution is small, which necessarily entails a large back titration. If, on the other hand, a weaker oxidizing solution is used, the maximum amount of organic material will not be oxidized. It is necessary, therefore, in each investigation to determine whether the maximum oxygen consumed or the maximum accuracy is desired. For example, when 0.025 N dichromate is used as the oxidizing agent, the values obtained are about 10 per cent lower than with the 0.2500 N reagent. The ferroin indicator is also less sensitive at this lower dichromate concentration. As a rule, the application of oxygen consumed methods to the study of polluted streams has been limited. Lawrance (27) (28) used the standard permanganate test in his study of the pollution of the Androscoggin River to determine the rate of application of sodium nitrate to prevent septicity.

Industrial Wastes

Perhaps the widest use of oxygen consumed methods in the future will be in the field of industrial waste

analyses. This is easily understandable, as such determinations require a relatively short time and, as mentioned before, many wastes contain materials which are toxic to the microflora and fauna responsible for biochemical action. This last factor is one of the major causes of the wide range in B.O.D. results obtained with various dilutions of toxic wastes. This is aptly illustrated by the range of B.O.D. values shown for the textile dye wastes and the oil refinery waste in Table VI.

There are, however, many industrial wastes for which oxygen consumed methods can give valuable information. For example, if a given waste is fairly consistent in composition, then a mean ratio between the oxygen consumed and B.O.D. may be determined. Once such a ratio is determined much time will be saved in the operation of a pilot plant to determine the best method for treatment of the particular waste. Whether or not the oxygen consumed test can be used to control the ultimate treatment process can only be determined after additional experimentation.

Table VI gives comparisons between oxygen consumed and 5-day B.O.D. of a few industrial wastes and a sample containing one of the common synthetic detergents. In the case of the first three wastes, a ratio between the two parameters should be fairly easy to determine. However, with the last two wastes variable B.O.D. results are obtained (depending on the dilution used) and such wastes would require extensive tests to determine the most probable ratio, and to use oxygen consumed methods as control measures.

Conclusions

1. The use of silver sulfate as a catalyst greatly extends the completeness of the oxidation by the acid dichromate procedure when the use of silver is compatible with the waste.

2. Oxygen consumed methods and the B.O.D. test are two distinctly different parameters indicating biological and chemical oxygen requirements, which have no *a priori* intrinsic relationship.

3. In those wastes containing materials toxic to biological action, or if the approximate chemical oxidizability of a given waste is desired, an oxygen consumed method can be used advantageously.

4. In domestic sewage from which the settleable solids have been removed, a satisfactory correlation can be obtained between the oxygen consumed and 5-day B.O.D.

5. In streams receiving domestic sewage the O.C./B.O.D. ratio increases as the stream becomes increasingly biologically stable. This is due to the presence of microflora and fauna containing organic compounds that are oxidized by chemical methods and are biologically stable.

6. Where a given industrial waste is fairly constant in composition and contains no toxic materials, a satisfactory O.C./B.O.D. ratio may be determined. In such cases, the oxygen consumed

TABLE VI.—Ratio of Oxygen Consumed to B.O.D. of Industrial Wastes

Waste	5-Day B.O.D. (p.p.m.)	Oxygen Consumed (p.p.m.)		O.C./B.O.D. Regular Method	
		Regular Method	Regular Plus Ag_2SO_4	Maximum	Minimum
Dye waste	450	1,180	—	2.62	—
Distillery waste	725	344	902	0.47	—
Sodium lauryl sulfate	1,300	1,530	1,800	1.18	—
Soap mfg. waste	303	530	—	1.74	—
Textile dye waste	280 to 2,000	37,600	—	134	18.8
Oil refinery waste	8,000 to 63,000	48,400	57,500	6.1	0.77

test, with occasional checks against B.O.D., may be used for control purposes in the treatment of the particular waste.

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VOLATILE ACID PRODUCTION DURING THE DIGESTION OF SEEDED, UNSEEDED, AND LIMED FRESH SOLIDS *

By A. Joel Kaplovsky **

A comparative study was made of the production of lower volatile acids during the digestion of seeded, unseeded, and limed fresh sewage solids. An attempt was made to correlate the total and individual volatile acid formation of the various mixtures during their digestion with the hope of obtaining pertinent information relative to the actual mechanism of decomposition of sewage solids. An actual comparison of each of these mixtures as to the types and concentrations of acids might lead to a better understanding of the most desirable conditions for rapid decomposition of sewage solids. No attempt was made to explain the complex phenomena associated with the degradation of sewage solids.

Gortner (2) differentiates volatile and non-volatile fatty acids. The fatty acids containing a maximum of 10 carbon atoms are classified as water-soluble fatty acids and those containing more than 10 carbon atoms are classified as insoluble fatty acids; lauric acid, having 12 carbon atoms, is slightly soluble in boiling water. The volatile fatty acids are the first six lower molecular weight acids classified as soluble fatty acids and are the only ones that can be distilled at atmospheric pressure. Because of their high vapor tension, these volatile acids can be removed from aqueous solution by steam distillation, in spite of the high boiling points. The insoluble or non-volatile fatty acids are oleic, stearic, palmitic, linoleic, and linolenic acids.

Heukelekian (3), in his studies on the course of volatile acid accumulation in the digestion of fresh solids under different conditions, showed that an intimate relationship exists between gas production and volatile acids. Unlimed solids reached a total volatile acid concentration of 2,500 p.p.m. (as CO_2) and remained at this level for a considerable time. In the limed fresh solids the high volatile acid level dropped in 60 days from 2,000 to 100 p.p.m. Volatile acids in the seeded mixture dropped in 30 days from 600 to 100 p.p.m. No attempt was made to identify the individual fatty acids.

Rawn, Banta, and Pomeroy (7) in their report of chemical studies on multi-stage sewage sludge digestion operation conducted over a period of four years showed that the volatile acids, expressed as acetic acid, varied from 148 to 77 p.p.m.

Buswell and Hatfield (1) contend that accumulation of organic acids and their salts to the extent of 2,000 to 6,000 p.p.m., as acetic, overtaxes the buffer capacity of the medium and if the accumulation of acids and acid salts is desired, alkalies should be added and the addition of alkalies should not be practiced if one is endeavoring to produce methane as the main end product. If the concentration is kept below 2,000 to 3,000 p.p.m., the methane fermentation proceeds with ease, provided the acid-fermenting organisms are present and the buffer capacity of the medium is sufficient to maintain

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the pH above 6.5. An attempt has been made to establish 2,000 p.p.m. total acid content as the maximum to be carried in a digestion tank, but the numerous exceptions to this acid level have consequently cast doubt as to the validity of this value. Volatile acid concentrations varied widely in the different decomposing mixtures.

The lower volatile acids found by Rawn, Banta, and Pomeroy (7) and Buswell and Hatfield (1) in digesting sewage solids and industrial wastes consisted of a combination of two or more of the following: formic, acetic, propionic, butyric, valeric, and caproic acid. The presence of valeric and caproic acids was suggested but not actually demonstrated.

Methods

This study was made of the lower volatile acid concentrations present in decomposing sewage solids under the following conditions: (a) unseeded; (b) limed; (c) properly digesting seeded 2 and 4 parts of volatile solids in fresh solids to 1 part of volatile solids in ripe sludge mixtures, respectively; and (d) improperly digesting seeded 2 and 4 parts of volatile solids in fresh solids to 1 part of volatile solids in ripe sludge mixtures, respectively.

In the unseeded fresh solids series, a sufficiently large sample of fresh solids was stored at 20° C. and at weekly intervals samples were drawn for analysis. Each sample was analyzed for individual volatile acids, percentage of solids, percentage of ash, and pH. In another series, a large batch of fresh solids was limed daily, and often more frequently, thereby keeping the pH as close to 7.0 as possible. In a third and fourth experimental series, seeded mixtures of fresh solids and ripe sludge were prepared, on the basis of 2:1 and 4:1 fresh solids to ripe sludge volatile matter ratio. The mixtures were incubated at 20° C. and daily gas measurements were made. Aliquots were drawn at various intervals from separate containers and analyzed for the individual acids present by the Werkman "partition" method (6). The third experimental series, consisting of both a 2:1 and a 4:1 seeded mixture, did not digest properly, possibly because of the presence of some industrial wastes, whereas the fourth series digested in a normal manner.

The volatile acids accumulated during digestion of each of the mixtures were removed for analyses by the "improved" method of volatile acid recovery (4) prior to the individual acid determinations.

Experimental Results

For simplicity, a compilation of significant data from the numerous experiments is presented (Table I). A wide range of digestion time is shown by the various experiments. Consequently, a rather complete picture of acid production with different rates of digestion was obtained. Starting with the most rapid, the properly digesting 2:1 mixture required 28 days for complete digestion; the intermediate rates are represented by the properly digesting 4:1 mixture (35 days), limed fresh solids (75 days) and improperly digesting seeded solids (133 days). The picture was completed with the unseeded fresh solids, requiring 217 days for digestion.

Both series of seeded fresh solids, the proper and improper digestions, are compared on the basis of the actual total acid production, which includes not only the weekly increases and decreases of the accumulated acids, but also the equivalent gas converted to p.p.m. as acetic acid. This gas conversion is based on the assumption that most of the gas evolved originates from the action of the methane organisms on the acetic acid molecules. Buswell and Hatfield (1) found that 1 g. of acetic acid will yield 750 ml. of gas, and this factor was used for the conversions. In the properly digesting seeded mixtures both the 2:1 and 4:1 mixtures agreed

TABLE I.—Compilation of Significant Data During Digestion of Seeded and Unseeded Fresh Solids

	Type of Digestion of Fresh Solids					
	Unseeded	Limed	Poorly Digesting Seeded		Properly Digesting Seeded	
			2:1 Ratio	4:1 Ratio	2:1 Ratio	4:1 Ratio
Digesting time (days)[1]	217	75	133	133	28	35
Total vol. acids (mg./g. vol. matter)[2]	—	—	753	377	600	573
Peak acid accum. in sludge (mg./g. vol. matter)	98	140	224	167	10.60	17.32
Time before acid content decreased in sludge (days)	98	16	76	62	5	5
Acid conc. in sludge when rapid gasification started (p.p.m.)	2,875[3]	1,590[3]	2,550[3]	2,833[3]	200	250
Max. acid accum. (mmoles/l.):						
Acetic	40.0	30.4	39.5	40.5	—[4]	3.18
Propionic	25.5	12.7	18.25	20.1	—[4]	6.95
Butyric	39.6	22.70	31.55	28.15	—[4]	13.25
Max. vol. acid accum. (% mol):[5]						
Acetic	59.5	63.0	60.5	59.0	—[4]	56.2
Propionic	32.5	77.5	83.0	84.5	—[4]	47.3
Butyric	83.2	78.0	73.5	76.0	—[4]	74.0
Vol. matter reduction (%)	37.8	—	30.3	22.9	47.0	48.5

[1] After maximum gas production all experiments were terminated when on two successive days approximately 5 ml. of gas per gram of volatile matter were produced.

[2] Includes gas equivalent converted to p.p.m. acetic acid.

[3] Taken when acetic acid concentration reached a low of 4 to 8 millimoles per liter.

[4] Distillate concentrations too low for "partition" analyses.

[5] Per cent molar is equivalent to percentage by weight of total volatile acids present.

rather well at 600 and 573 mg. of total volatile acids per gram of volatile matter, respectively. The poorly digesting 2:1 mixture differed appreciably from either of the properly digesting mixtures with a total accumulation of 753 mg. of volatile acids per gram of volatile matter. It is possible that the assumption that the gas is produced from acetic acid may not apply in this case of abnormal digestion and that the path of methane formation is not through acetic acid in this case, but through some other compound which has a lower gas equivalent than the assumed. The improper digestion resulted in a volatile matter reduction of only 30.3 per cent, as compared to 47.0 per cent for the normally digesting seeded mixture. The slowly digesting seeded mixture (2:1) did not begin accelerated gasification until the 98th day, when approximately 400 mg. of volatile acids per gram of volatile matter had accumulated.

The low total volatile acids obtained with the 4:1 improperly digesting mixture can be explained by the fact that digestion was not complete even after 133 days; the digestion mixture still contained 1,925 p.p.m. of total volatile acids and the volatile matter reduction amounted to only 22.9 per cent.

Peak acid accumulation in the sludge mixtures varied widely but logically. The acid accumulation with unseeded fresh solids was lower than with the limed or the poorly digesting seeded mixtures. Acid hydrolysis was more concentrated or extensive during the earlier weeks of digestion with the improperly digesting seeded mixtures than with the unseeded solids because, in all probability, the added seed stimulated acid production but conditions were still unfavorable for rapid acid

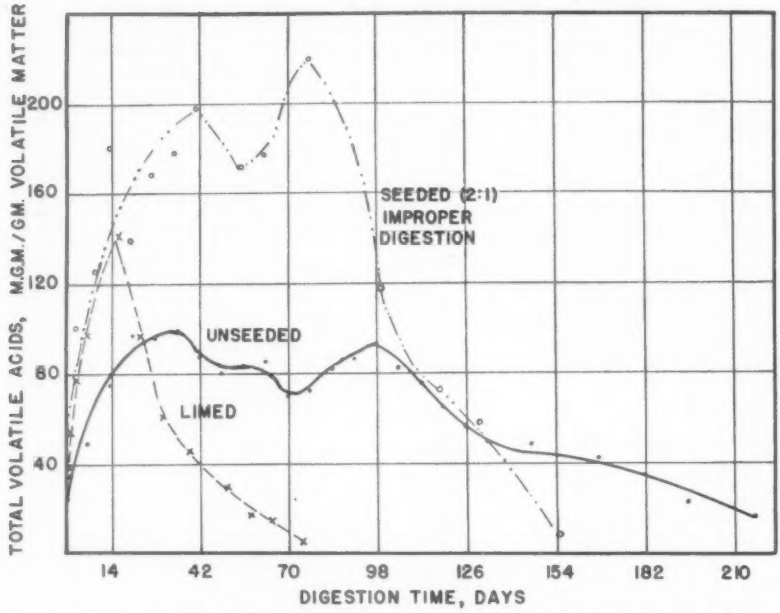

FIGURE 1.—Comparison of total volatile acid concentrations from limed, unseeded, and seeded but improperly digesting fresh solids.

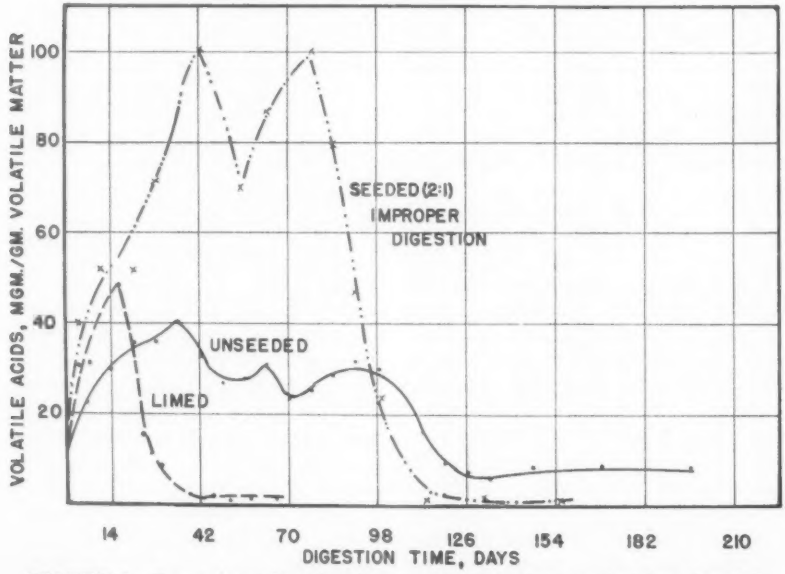

FIGURE 2.—Comparison of acetic acid accumulation during the digestion of seeded, limed, and unseeded fresh solids.

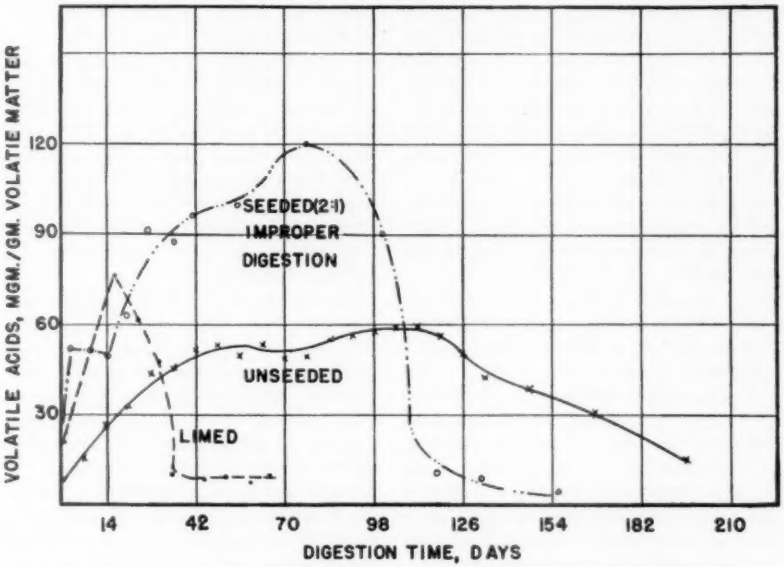

FIGURE 3.—Comparison of butyric acid accumulation during the digestion of seeded, limed, and unseeded fresh solids.

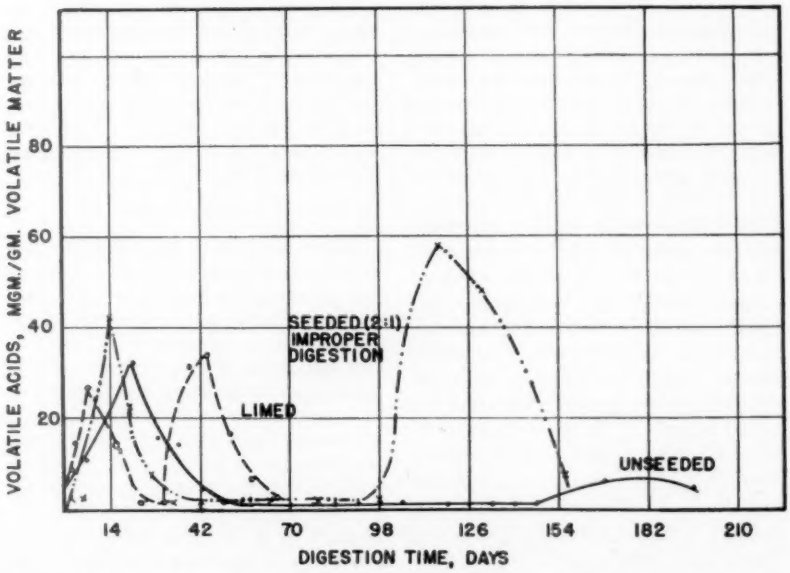

FIGURE 4.—Comparison of propionic acid accumulation during the digestion of seeded, limed, and unseeded fresh solids.

destruction and consequent gasification. In the limed fresh solids the acids accumulated to a higher level than in the unseeded solids because a greater rate of hydrolysis was induced by the lime additions. The lower acid level of the limed, as compared with the improperly digesting mixture, can be attributed to the more favorable environmental conditions for digestion. Apparently, during the digestion of the improperly seeded mixtures the activity of the methane-producing or acid-destroying organism was retarded, thus permitting acid accumulation and low gas production.

A correlation between the acid concentration in the various sludge mixtures and the time when rapid gasification commenced was attempted. With the two improperly digesting mixtures there was an approximately equal volatile acid concentration in the sludge at the time gasification increased appreciably. Each mixture had an acetic acid concentration between 4 and 8 millimoles per liter at the start of rapid gasification. When an acetic acid concentration level of 4 to 8 millimoles per liter was applied to the unseeded fresh solids, about the same quantity of acetic acid was found at the start of gasification as in the poorly digesting seeded mixture. Gasification started at an appreciably lower acetic acid concentration in the limed fresh solids. Hence, it does not seem likely that a definite acid concentration level can be established at which rapid gasification or proper digestion will take place.

The maximum individual acid accumulation in the various mixtures showed certain similarities, with the exception of the properly digesting 4:1 seeded mixture. In all the slowly digesting mixtures acetic acid was found in greatest concentration and propionic acid the least. The properly digesting seeded 4:1 mixture had less acetic acid than either propionic or butyric acid. This may be attributed to the continuous rapid conversion of acetic acid to gas under the more favorable condition of digestion.

The maximum percentage by weight of total volatile acids present (expressed as molar per cent of acetic acid found) averaged 60, with only small deviations from the average. This was very striking. Butyric acid also gave rather consistent maxima. No uniformity existed with the propionic acid molar per cent maxima in the various mixtures.

A comparison of total volatile acid concentrations from limed, unseeded, and seeded but improperly digesting fresh solids is shown in Figure 1. The rates of acid hydrolysis differed markedly. Limed fresh solids show a rapid increase of accumulated acids and their almost complete disappearance after 75 days of digestion. Unseeded fresh solids had the slowest rate of hydrolysis of all three mixtures, as indicated by a slower initial acid increase and a much longer digestion time to reach a low acid level.

A comparison of individual acid accumulation during the digestion of the above variously treated fresh solids is presented in Figures 2, 3, and 4. Figure 2 shows the acetic acid accumulation of each of the experiments. In similar manner, Figure 3 presents butyric acid, and Figure 4, propionic acid accumulations.

Discussion

There appears to be a difference of opinion as to the value of lime as an aid to sewage solids digestion. Buswell and Hatfield (1) report that the addition of lime as a means of controlling pH is not the proper approach to solving acid conditions, as the addition of lime accelerates the production and accumulation of organic acids by neutralizing the free acids. They report, further, that the methane-producing organisms apparently work best in the absence of high concentrations of organic acid salts, and alkalies should not be added if one is endeavoring to produce methane as the main end product.

To keep digestion operating properly, not only must the reaction be controlled, but also the conditions for the methane-producing organisms must be favorably maintained. Heukelekian (4) has shown that the methane organisms are extremely sensitive to pH changes. As it has been shown that lime does not alter the manner of decomposition, but merely increases the rate of hydrolysis as compared to improperly digesting solids, there appears to be no reason why, if conditions are still reasonably favorable for methane organisms, the prevention of pH lowering by means of lime additions should not be advantageous. It is possible that the accumulation of volatile acids found by Buswell and his co-workers occurred to such an extent that the activity of methane organisms was considerably decreased and adding lime after such a condition prevailed may have increased the rate of hydrolysis and consequently further acid accumulation. The inability to restore normal digestion and gasification was not caused by the effect of lime, but resulted from the fact that the proper flora was not at its peak activity. To further substantiate the above reasoning, Buswell himself gives a very wide range of 2,000 to 6,000 p.p.m. organic acids as being detrimental to digestion because of the overtaxing of buffer capacity of the medium. It had been shown that with properly digesting seeded solids, rapid gas production does not commence even with a low of 148 p.p.m. total volatile acids. Apparently, the volatile acid accumulation is only a secondary factor, as without the proper active bacterial flora trouble will be encountered even at a low volatile acid level. Consequently, it appears that lime additions can be of considerable aid in controlling digestion if administered at the proper time. If volatile acids begin to accumulate above the level of approximately 100 p.p.m. for seeded fresh solids (that is, over 200 to 300 p.p.m.) need for liming would be indicated, since waiting for a level of 2,000 to 6,000 p.p.m. to be reached will most likely retard the activity of methane-producing organisms. Judicious liming would prevent the unfavorable reaction and prevent harm to the flora present. The fact that limed fresh solids digested in 75 days, as compared with 217 days required for the digestion of unlimed material, illustrates once again that liming is beneficial for the digestion of sewage solids.

No gas measurements were made on the lime or untreated fresh solids, but if a comparison is made with published results obtained under similar conditions (8), it is clear that gas production is directly related to the presence of enzymes and corresponds to the volatile acid accumulation found in this study.

In all four experiments the gas production rate increased most rapidly shortly after the volatile acid accumulation had passed its peak and began to descend. As soon as the methane-producing organisms were present in sufficient numbers, the volatile acid level was lowered because the rate of conversion of the acids to methane was greater than the rate at which they were reduced. Thus, the lowering of the acid level is the result of the greater rate of destruction and not of the lower rate of production. Reaction control is not the only important factor, because even with controlled pH, as in the limed solids, rapid gasification did not begin until the proper number of methane-producing organisms was developed.

A comparison of individual acid accumulations during the digestion of variously treated fresh solids as presented in Figures 2, 3, and 4 for acetic, butyric, and propionic acids, respectively, shows that the trend of individual acid production is identical in all three experiments. Propionic acid gave two distinct peaks in each experiment. Possibly, compounds such as lactic acid are originally present or are produced during the digestion of fresh solids and thus provide the source of

TABLE II.—Composition of Volatile Acids at Beginning of Rapid Gasification

	Untreated Fresh Solids	Limed Fresh Solids	Improperly Digesting Seeded Fresh Solids	Properly Digesting 4:1 Seeded
Acetic acid (% mol)	28.0	26.2	26.5	26.0
Propionic acid (% mol)	0.0	0.0	0	0.0
Butyric acid (% mol)	72.0	73.8	73.5	74.0
Total vol. acids (p.p.m.)	4,409	6,975	2,574	250
Volatile matter (mg./g.):				
Acetic acid	0.0	0.0	0.0	0.0
Butyric acid	60.2	61.2	90.4	14.40
Beginning of rapid gasification period (days)	112	23	98	14
Ratio of acetic-butyric acid concentration	1:3.8	1:4.1	1:4.0	1:4.1

the first propionic acid peak. The second peak may be attributed to the propionic acid production from more complex substances. Apparently, hydrolysis of complex substances was identical in all three mixtures, but differed in their respective rates. The more rapid hydrolysis occurred with the limed fresh solids, excluding properly digesting seeded mixtures, and the slowest hydrolysis occurred in the untreated fresh solids.

Another interesting observation may be made in regard to the composition of the volatile acid mixtures when rapid gasification began (Table II).

All four mixtures show that the acetic acid and butyric acid contents, expressed as per cent molar, were almost identical. There is an approximately constant ratio of 1 : 4.0 of acetic to butyric acid at the start of gasification. The significance of this ratio is at present obscure. Although propionic acid was not found during the period of the increased gas rate, it appeared later in all except the properly digesting 4:1 mixture. In that mixture the acid concentration was too low for analysis during the later stage of digestion and propionic acid may have been present in the mixture.

Conclusions

1. During the decomposition of seeded, limed, and unseeded fresh solids only three volatile acids occurred in measurable quantities—namely, acetic, propionic, and butyric acids.

2. In the slowly digesting fresh solids mixtures, acetic and butyric acid accumulations were similar; they increased rapidly to a maximum concentration and remained at that level until more favorable digestion conditions prevailed.

3. Propionic acid appeared during the digestion of limed, unlimed, and seeded fresh solids in two separate peaks, with no propionic acid accumulation in between. The first peak occurred early during the digestion; the second appeared during the last stage of decomposition of the solids.

4. The accumulation and decomposition of individual acids during the digestion of the variously treated fresh solids were similar in amount but differed in rate.

5. Liming of fresh solids does not alter the manner of decomposition of the solids, but increases the rate of hydrolysis.

6. In properly digesting seeded solids the total volatile acids accumulate initially and then decrease rapidly as the rate of gasification increases.

7. In digesting sewage solids an acetic—butyric acid ratio of 1 : 4.0 occurs, beginning with rapid gasification. Propionic acid is absent during this stage of digestion.

8. In digesting mixtures the trend of acetic acid accumulation varied with

the total volatile acids per unit amount of sludge solids. The acetic acid concentration did not exceed 40 millimoles per liter. Gasification started at a level of 4 to 8 millimoles per liter.

9. In the properly digesting seeded mixtures rapid gasification began when the total volatile acids in the sludge mixture reached the low level of 9 to 11 mg. per gram of volatile matter after peak acid accumulation. The time required to reach this low level corresponds to the usual initial lag period of batch digestion.

10. After rapid gasification began with properly digesting seeded solids, the total acids dropped further and remained at a low level of approximately 3.6 mg. per gram of volatile matter throughout the entire period of rapid gasification.

11. The total volatile acid production per gram of volatile matter added, including the acids remaining in the sludge and those converted to gas, were approximately the same whether the seeded mixture was digested properly or improperly. This total volatile acids concentration approximated 600 mg. per gram of volatile matter.

Summary

An attempt was made to correlate the total and individual volatile acid formation from various mixtures of fresh solids and ripe sludge during their digestion with the hope of obtaining pertinent information relative to the actual mechanism of decomposition of sewage solids.

A comparison based on the volatile acids and gas production of differently seeded fresh solids mixtures was made with limed fresh solids to determine the effect of lime on digestion of solids.

Acknowledgment

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HYDRAULIC BEHAVIOR OF STORM-WATER INLETS

II. FLOW INTO CURB-OPENING INLETS

By Wen Hsiung Li, Knut K. Sorteberg, and John C. Geyer

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This article is the second of a series of reports on the hydraulics of storm drain inlets, a research study sponsored by Baltimore City, Baltimore County, and the Maryland State Roads Commission and conducted by the Institute of Cooperative Research of The Johns Hopkins University. All work is under the direction of the Sanitary Engineering Department of the University in cooperation with the Department of Civil Engineering. The first article of this series (1) presented the result of an investigation on grate inlets in a straight gutter without depression. This second article deals with curb-opening inlets with and without local depression in the gutter.

The tests reported here were conducted on the gutter model described in the first article of this series (1) with inlet models of 1:3 scale. The general layout of the inlets investigated is shown in Figures 1 and 2. In the case of a gutter with a local depression (see Figure 2), the depression is of a constant width, with transitions beginning at the ends of the curb opening. This arrangement is believed to be representative of the curb-opening inlets generally adopted in practice. Inlets of different lengths and streets at different grades and crowns were included in the investigation. With each arrangement, the inlet capacities for different quantities of gutter flow were observed. In most cases, quantities of gutter flow giving carry-over flow (that is, portion of the flow that did not go into the inlet) as much as 20 and 40 per cent were used for cases of inlets with and without local depressions, respectively.

As in the earlier work, dimensional analysis is employed in the analysis of the data; included are all physical variables that may affect the inlet capacity.

Letter Symbols

In this article, the following symbols are used (see Figures 1 and 3):

Q_0 = quantity of gutter flow (c.f.s.)
Q = discharge into inlet (c.f.s.)
q = carry-over flow passing inlet (c.f.s.)
y_0 = depth of gutter flow at curb (ft.)
y = depth of flow at curb at the upstream end of inlet opening (ft.)
A_0 = cross-sectional area of gutter flow corresponding to y_0 (sq. ft.)
A = cross-sectional area of flow corresponding to y (sq. ft.)
θ_0 and θ = angle between cross-section of street and vertical
v_0 = mean velocity of gutter flow (ft. per sec.)

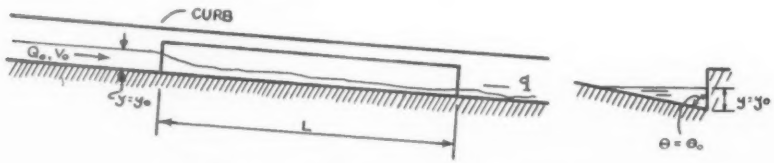

FIGURE 1.—Curb-opening inlet without depression.

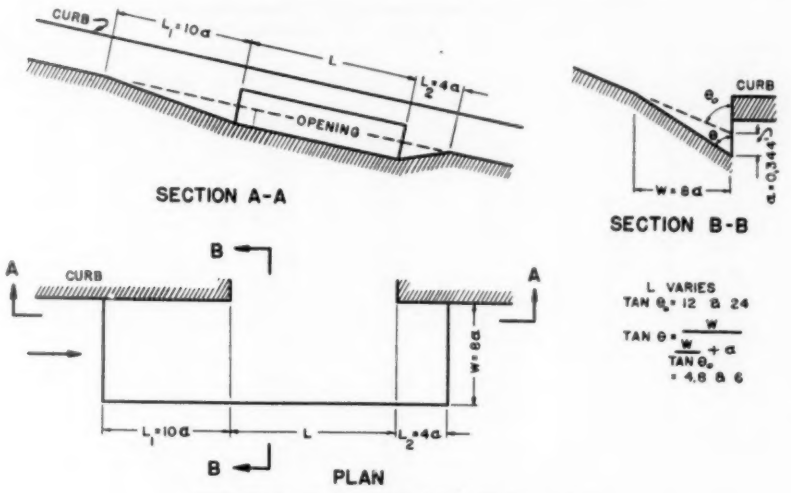

FIGURE 2.—Curb-opening inlet with depression.

v = mean velocity of flow at upstream end of inlet opening (ft. per sec.)
s = street grade (ft. per ft.)
n = Manning's roughness coefficient for gutter
L = length of inlet opening (ft.)
L_1 = length of upstream transition of depression (ft.)
L_2 = length of downstream transition of depression (ft.)
w = width of depression (ft.)
a = depth of depression at curb (ft.)
b = rise at end of depression (ft.) (see Figure 4)
$a' = (b - L_2 s)/(1 - 4s)$
g = gravitational force per unit mass (gravitational acceleration) (ft. per sec. per sec.)
$E = \frac{v^2}{2g} + y$ (ft.)
$F = v^2/gy$
K and C = constants

Other symbols used are defined where they first appear.

Curb-Opening Inlet Without Gutter Depression

The discharge, Q, into a curb-opening inlet without gutter depression (see Figure 1) depends upon the inlet length, L; the acting force, g; the carry-over flow, q; and the characteristics of the approaching flow, v and θ. (For inlets without depressions $v = v_0$, $y = y_0$ and $\theta = \theta_0$.) The slope and roughness of the gutter have been taken care of in the values of v, y, and θ.

Thus, Q is related to L, g, q, v, y, and θ. As these seven variables can be expressed in terms of two fundamental physical dimensions (namely, length and time), there can only be five independent dimensionless quantities, say,

$$\frac{Q}{Ly\sqrt{gy}}, \frac{v}{\sqrt{gy}}, \frac{q}{Q}, \theta, \text{ and } \frac{Q+q}{v\,y^2\tan\theta}$$

Inasmuch as $(Q + q) = v_0\, y_0^2 \tan\theta_0/2 = v\, y^2 \tan\theta/2$, the last quantity is a constant, numerically equal to 1/2. Therefore,

$$\frac{Q}{L\,y\sqrt{gy}} = \phi\left(\frac{v}{\sqrt{gy}}, \frac{q}{Q}, \theta\right)$$

Tests were made with $v/\sqrt{gy}$ ranging from 1 to 3, q/Q ranging from 0 to 0.7, and $\tan\theta$ (or in this case $\tan\theta_0$) equal to 12, 24, and 48. The data from these tests show that

$$\frac{Q}{L\,y\sqrt{gy}} = K \text{ or } \frac{Q}{L\,y_0\sqrt{g\,y_0}} = K \quad (1a)$$

TABLE I.—Data on Curb-Opening Inlets Without Depression
(Street Crown, 1 In. Per Ft.; Model Scale, 1:3)[1]

Slope (ft./ft.)	Length, L (ft.)	Depth, y (ft.)	Gutter Flow, Q_0 (c.f.s.)	Carry-over, q (c.f.s.)	Observed Q (c.f.s.)	Computed Q (c.f.s.)
0.04	9.00	0.186	1.25	0.38	0.87	0.94
		0.150	0.80	0.14	0.66	0.68
		0.141	0.59	0.02	0.57	0.62
		0.138	0.54	0	0.54	0.60
	7.20	0.174	1.00	0.38	0.62	0.68
		0.144	0.63	0.14	0.49	0.51
	6.69	0.105	0.31	0	0.31	0.30
	6.18	0.150	0.88	0.40	0.48	0.47
		0.141	0.53	0.15	0.38	0.42
	4.89	0.249	2.70	1.87	0.83	0.80
0.03	9.93	0.198	1.03	0	1.03	1.14
	9.00	0.264	2.29	0.74	1.55	1.59
		0.216	1.40	0.25	1.15	1.18
		0.198	1.03	0.07	0.96	1.03
	8.76	0.168	0.77	0	0.77	0.79
	7.23	0.216	1.40	0.46	0.94	0.95
		0.168	0.76	0.11	0.65	0.65
	6.75	0.138	0.45	0	0.45	0.45
	6.63	0.144	0.42	0	0.42	0.47
	6.18	0.198	1.03	0.34	0.69	0.71
		0.180	0.83	0.21	0.62	0.62
		0.144	0.42	0.03	0.39	0.44
	4.86	0.222	1.37	0.75	0.62	0.66
		0.144	0.42	0.10	0.32	0.34
		0.096	0.16	0	0.16	0.19
	3.06	0.234	1.37	0.97	0.40	0.45
		0.144	0.47	0.24	0.23	0.22
		0.072	0.08	0	0.08	0.08
0.02	9.00	0.345	4.40	1.85	2.54	2.39
		0.243	1.80	0.37	1.43	1.41
		0.210	1.17	0.06	1.11	1.13
		0.201	1.02	0	1.02	1.06
	7.20	0.315	3.75	1.90	1.85	1.66
		0.306	2.71	1.20	1.51	1.59
		0.195	1.07	0.18	0.89	0.81
	6.18	0.285	2.99	1.56	1.43	1.23
		0.225	1.48	0.56	0.92	0.87
		0.174	0.82	0.14	0.68	0.59
	4.89	0.228	1.56	0.83	0.73	0.70
		0.189	0.90	0.32	0.58	0.53
	3.06	0.216	1.29	0.85	0.44	0.40
		0.075	0.09	0	0.09	0.08

where K depends on θ only. For $\tan\theta$ $(= \tan\theta_0) = 12$, 24, and 48, $K = 0.23$, 0.20, and 0.20, respectively. Test data for $\tan\theta_0 = 12$ are shown in Table I.

As Eq. 1a has been obtained for cases where the value of $v/\sqrt{g\,y}(= v_0/\sqrt{g\,y_0})$ is as high as 3, it can be applied with confidence for cases where $\sqrt{s}/n$ is less than about 22. (It was shown in the previous article that $v_0/\sqrt{g\,y_0} \cong 0.14\sqrt{s}/n$.)

Design Curves for Inlets Without Depression

It has been demonstrated in the previous article of this series of reports that, when the cross-slope at the gutter is uniform and is defined by $\tan\theta_0$,

TABLE I.—Data on Curb-Opening Inlets Without Depression (Street Crown, 1 In. Per Ft.; Model Scale, 1:3)—Continued

Slope (ft./ft.)	Length, L (ft.)	Depth, y (ft.)	Gutter Flow, Q_0 (c.f.s.)	Carry-over, q (c.f.s.)	Observed Q (c.f.s.)	Computed Q (c.f.s.)
0.01	9.00	0.342	3.06	0.75	2.31	2.35
		0.270	1.81	0.16	1.65	1.65
		0.240	1.36	0.02	1.34	1.38
		0.219	1.16	0	1.16	1.20
	7.20	0.303	2.28	0.69	1.59	1.57
		0.249	1.56	0.27	1.29	1.17
		0.213	1.03	0.06	0.97	0.93
		0.201	0.86	0	0.86	0.85
	6.24	0.153	0.49	0	0.49	0.49
	6.18	0.234	1.42	0.43	0.99	0.92
		0.219	1.07	0.24	0.83	0.83
		0.177	0.67	0.07	0.60	0.60
		0.159	0.52	0	0.52	0.51
	4.89	0.201	0.92	0.30	0.62	0.58
		0.192	0.75	0.21	0.54	0.54
		0.153	0.48	0.07	0.41	0.38
		0.126	0.29	0	0.29	0.29
	3.06	0.225	1.09	0.66	0.43	0.43
0.005	7.20	0.336	2.14	0.43	1.71	1.83
		0.225	1.49	0.16	1.33	1.21
		0.243	1.06	0.01	1.05	1.12
		0.204	0.89	0	0.89	0.87
	6.15	0.318	1.90	0.50	1.40	1.44
		0.267	1.25	0.16	1.09	1.10
		0.234	0.91	0.02	0.89	0.91
	4.86	0.294	1.48	0.48	1.00	1.01
		0.249	1.00	0.22	0.78	0.79
		0.201	0.60	0.03	0.57	0.57
		0.168	0.39	0	0.39	0.43
	3.06	0.249	0.91	0.41	0.50	0.50
		0.186	0.50	0.14	0.36	0.32

[1] Values given are for the prototype.

Manning's formula for open-channel flow gives

$$y_0 = 1.326 \frac{(1 + \sec\theta)^{1/4}}{(\tan\theta_0)^{5/8}} \left(\frac{Q_0}{\sqrt{s}/n}\right)^{3/8}$$

and

$$v_0 = 1.14 \frac{(\tan\theta_0)^{1/4}}{(1 + \sec\theta_0)^{1/2}} \left(\frac{\sqrt{s}}{n}\right)^{3/4} Q_0^{1/4}$$

With these expressions, Eq. 1a for the capacity of curb-opening inlets without local depression can be rewritten as

$$\frac{Q}{L} = 8.7K \frac{(1 + \sec\theta_0)^{3/8}}{(\tan\theta_0)^{15/16}} \left(\frac{Q_0}{\sqrt{s}/n}\right)^{9/16} \quad (1b)$$

where K is equal to 0.23, 0.20, and 0.20 for $\tan\theta_0$ equal to 12, 24, and 48, respectively. Figure 4 has been prepared to facilitate the solution of Eq. 1b.

Eq. 1b applies to gutters with a straight crown. If the gutter cross-slope is not straight within the width of gutter flow, the mean cross-slope within the width of gutter flow should be used.

Example.—Given gutter flow = 2 c.f.s., street grade = 3 per cent, $n = 0.015$, and $\tan\theta_0 = 12$. Find the length of a curb-opening inlet required to capture 90 per cent of the gutter flow. Also find the capacity of a 7-ft. curb-opening inlet.

Here $\dfrac{Q_0}{\sqrt{s}/n} = \dfrac{2}{\sqrt{0.03}/0.015} = 0.173.$

With $\tan\theta_0 = 12$, $\dfrac{Q}{L} = 0.19$ from Figure 4.

TABLE II.—Data on Curb-Opening Inlets with Depression (Street Crown, 1 In. Per Ft.; Model Scale, 1:3)[1]

Dimensions of Prototype:

Depth of depression, $a = 0.344$ ft.
Length of upstream transition, $L_1 = 10a = 3.44$ ft.
Length of downstream transition, $L_2 = 4a = 1.38$ ft.
Width of depression, $w = 8a = 2.75$ ft.

$$\tan\theta = \frac{w}{\frac{w}{\tan\theta_0} + a} = \frac{8a}{\frac{8a}{12} + a} = 4.8$$

Street Grade, s (ft./ft.)	Calibrated Manning's n	Opening Length, L (ft.)	Gutter Flow, Q_0 (c.f.s.)	Observed Capacity, Q (c.f.s.)	Computed Capacity, Q (c.f.s.)
0.005	0.0068	3.00	2.32	2.23	2.24
			2.82	2.62	2.62
			3.23	2.92	2.91
			3.64	3.12	3.12
			4.04	3.35	3.39
0.01	0.0080	3.00	1.17	1.16	1.16
			1.34	1.32	1.30
			1.45	1.36	1.38
			1.72	1.56	1.56
			2.03	1.79	1.82
			2.43	2.10	2.07
			2.82	2.38	2.42
			3.14	2.51	2.49
0.02	0.0097	3.00	0.77	0.75	0.75
			1.00	0.87	0.93
			1.47	1.23	1.24
			1.76	1.41	1.44
			2.08	1.56	1.64
			2.26	1.64	1.75
		5.00	1.87	1.86	1.87
			2.68	2.62	2.66
			2.88	2.79	2.81
			3.29	3.06	3.08
			3.59	3.30	3.26
			3.90	3.46	3.47
			4.27	3.62	3.67
		7.00	5.20	5.17	5.20
			5.54	5.44	5.40
0.03	0.0108	3.00	0.67	0.65	0.65
			0.83	0.73	0.76
			1.01	0.89	0.91
			1.39	1.10	1.10
			1.65	1.12	1.20
		5.00	1.90	1.82	1.90
			2.34	2.17	2.22
			2.70	2.34	2.42
			2.95	2.51	2.67

[1] Values given are for the prototype.

TABLE II.—Data on Curb-Opening Inlets with Depression (Street Crown, 1 In. Per Ft.; Model Scale, 1:3)—Continued

Street Grade, s (ft./ft.)	Calibrated Manning's n	Opening Length, L (ft.)	Gutter Flow, Q_0 (c.f.s.)	Observed Capacity, Q (c.f.s.)	Computed Capacity, Q (c.f.s.)
0.03	0.0108	7.00	3.54	3.54	3.52
			3.96	3.94	3.88
			4.31	4.21	4.02
			4.70	4.49	4.42
			4.82	4.42	4.46
			5.15	4.53	4.70
			5.65	4.70	4.91
0.04	0.0106	3.00	0.53	0.52	0.47
			0.87	0.73	0.70
		5.00	1.40	1.40	1.29
			2.32	1.87	1.84
			2.65	1.92	2.00
			3.09	2.09	2.24
		7.00	2.64	2.64	2.46
			3.09	2.96	2.71
			3.52	3.16	2.98
			4.25	3.58	3.35
			5.00	3.91	3.79
			5.70	4.18	4.06
		9.00	4.55	4.55	4.20
			4.85	4.80	4.35
0.05	0.0128	3.00	0.37	0.37	0.37
			0.93	0.81	0.78
		5.00	1.26	1.26	1.26
			1.39	1.26	1.34
		7.00	2.92	2.62	2.86
			3.70	3.05	3.32
			4.75	3.59	3.94
			5.62	4.06	4.36
		9.00	4.64	4.39	4.52
			5.23	4.85	4.91
			5.70	5.25	5.14
0.06	0.0128	3.00	0.39	0.38	0.38
			0.55	0.50	0.48
			0.69	0.58	0.57
		5.00	0.97	0.97	0.97
			1.12	1.02	1.09
		7.00	1.90	1.84	1.90
			2.18	1.96	2.13
			2.42	2.09	2.28
			2.65	2.26	2.48
			2.90	2.40	2.60

TABLE II.—Data on Curb-Opening Inlets with Depression (Street Crown, 1 In. Per Ft.; Model Scale 1:3)—Continued

Street Grade, s (ft./ft.)	Calibrated Manning's n	Opening Length, L (ft.)	Gutter Flow, Q_0 (c.f.s.)	Observed Capacity, Q (c.f.s.)	Computed Capacity, Q (c.f.s.)
0.06	0.0128	9.00	3.45	3.35	3.45
			4.06	3.78	3.86
			4.28	3.92	3.98
			4.71	4.30	4.30
			5.10	4.61	4.52
			5.46	4.89	4.65
0.08	0.0140	3.00	0.39	0.39	0.37
		5.00	0.86	0.85	0.86
			0.92	0.81	0.89
		7.00	1.98	1.82	1.92
		9.00	3.26	2.97	3.18
			3.76	3.34	3.52
			4.12	3.62	3.70
			5.09	4.40	4.20
			5.59	4.79	4.49

For $Q = 0.9 \times Q_0 = 1.8$ c.f.s., the required $L = 1.8/0.19 = 9.5$ ft.

If $L = 7$ ft., $Q = 0.19 \times 7 = 1.33$ c.f.s. and carry-over $q = Q - Q_0 = 0.67$ c.f.s.

Curb-Opening Inlet with Gutter Depression

For curb-opening inlets with gutter depression (see Figure 3), Eq. 1a must be modified for the following reasons:

1. In the case of curb-opening inlets without depression, $y = y_0$. When there is a depression, the depth, y, at the upstream end of the opening is different from the depth of gutter flow, y_0, and, therefore, the latter cannot be used in Eq. 1a.
2. Due to the presence of the depression, water is generally backed up near the downstream end of the opening in the form of a hydraulic jump, thus increasing the flow into the inlet.

To make the finding of depth y reasonably simple, it is necessary to assume that the upstream transition of the depression is sufficiently long that the water surface at the upstream end of the inlet is practically horizontal laterally. That this assumption is proper for the depressions used in this study is indicated by the close agreement between observed and computed inlet capacities (Table II).

The value of y can now be computed from the elements of the gutter flow as follows: By the principle of conservation of energy, the total head at the beginning of the upstream transition is related to that at the end of the same transition by

$$\frac{v_0^2}{2g} + y_0 + z = \frac{v^2}{2g} + y + \text{loss of head in transition } L_1$$

(see Figure 3). Assuming that the energy gradient in the transition is practically the same as the street grade, s (as for uniform gutter flow), the loss of head in the transition L_1 is then equal to $s\,L_1$. Since $z = s\,L_1 + a$, $v_0 = Q_0/A_0$, and $v = Q_0/A$, the above expression can be transformed into

$$\frac{Q_0^2}{2g\,A^2} + y = \frac{Q_0^2}{2g\,A_0^2} + y_0 + a \quad (2)$$

As the cross-sectional area of flow, A, is determined by the depth, y, the value of y can be obtained from Eq. 2 for a

given depression under a given condition of gutter flow.

With the approaching flow at the upstream end of the curb opening defined by the depth, y, the mean velocity, v, and the discharge, Q_0, the discharge, Q, into the inlet may depend upon the angle θ (or the average value of θ within the width of flow in the depression if this width is greater than the width, w, of the depression), the length of opening, L, the depression depth, a, the length of downstream transition, L_2, the carry-over flow, q, and the acting force, g. By dimensional analysis, these ten quantities give eight dimensionless terms, say,

$$\frac{Q}{L\,y\sqrt{g\,y}},\ \frac{v^2}{g\,y},\ \frac{L}{a},\ \theta,\ \frac{L_2}{a},\ \frac{q}{Q_0},\ \frac{Q+q}{Q_0},$$

and

$$\frac{Q_0}{v\,y^2\tan\theta}$$

As the last two terms are constants, numerically equal to 1 and 1/2, respectively, the other six terms can be related as follows:

$$\frac{Q}{L\,y\sqrt{g\,y}} = \phi\left(\frac{v^2}{g\,y},\ \frac{L}{a},\ \theta,\ \frac{L_2}{a},\ \frac{q}{Q_0}\right)$$

If, for convenience, Eq. 1a is modified for inlets with depression by introducing an additional term, C, to account for the increase of Q due to backwater,

$$\frac{Q}{L\,y\sqrt{g\,y}} = K + C \qquad (3)$$

Where K has been found to be dependent on the angle θ only, it is obvious that

$$C = \phi_2\left(\frac{v^2}{g\,y},\ \frac{L}{a},\ \theta,\ \frac{L_2}{a},\ \frac{q}{Q_0}\right)$$

Tests were conducted on the model with $v^2/g\,y$ ranging from 2 to 9 (produced with street grade ranging from 0.5 to 8 per cent in the model), L/a ranging from 8.7 to 26, $\tan\theta$ equal to 4.8 and 6.0 (resulting from $w = 8a$ with $\tan\theta_0 = 12$ and 24, respectively—see Figure 2), L_2/a equal to 4, q/Q_0 ranging from 0 to 0.2, and L_1/a equal to 10. The data from these tests show that

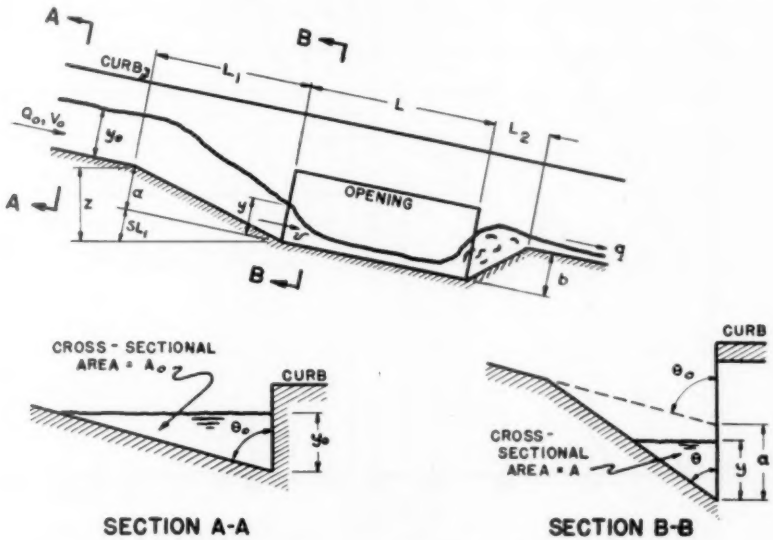

FIGURE 3.—Curb-opening inlet and flow dimensions.

with $K = 0.23$,

$$C = \frac{0.45}{1.12^M} \qquad (4a)$$

in which $M = \frac{LF}{a \tan\theta}$ and $F = v^2/gy$. In Table II are shown the test data for $\tan\theta = 4.8$, with the computed values of Q according to Eqs. 3 and 4a.

As with all empirical formulas, these equations can be used with confidence only for conditions covered by the tests from which they have been obtained. In Figure 5, Eq. 4a is shown graphically, with its field of application in full lines. However, the range of conditions covered by the experiments has been so wide that Eq. 4a is applicable

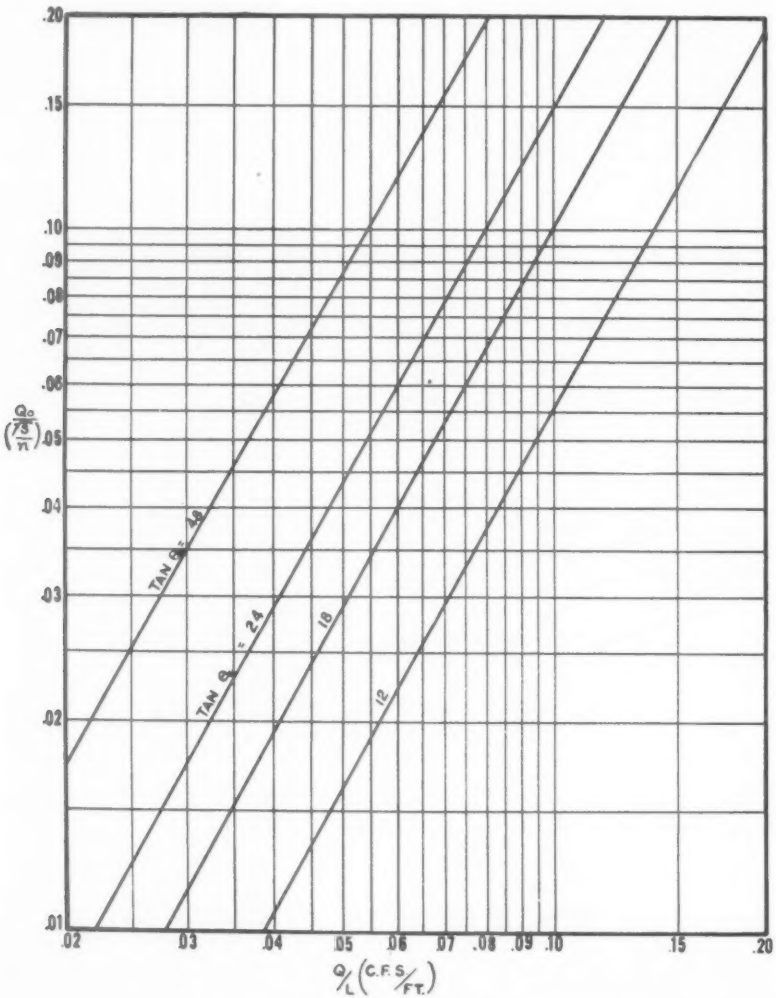

FIGURE 4.—Capacity of curb-opening inlets without depression.

to most, if not all, conditions that may be encountered in practice. It should also be mentioned that the length of the upstream transition, L_1, should be about ten times or more the depth of depression, a. This requirement is invariably met in general practice.

Eq. 4a has been obtained with the length of the downstream transition, L_2, equal to 4 times the depth of depression, a. For cases where the distance b (see Figure 6) is different from a, or where L_2/a is not equal to 4, it is recommended that Eq. 4a be modified to

$$C = \frac{0.45}{1.12^N} \qquad (4b)$$

in which

$$N = \frac{LF}{a' \tan\theta} \quad \text{and} \quad a' = \frac{b - L_2 s}{1 - 4s}$$

Here a' is the depth of depression, which, with a downstream transition $4a'$ in length, gives the same vertical rise as that of the given depression with dimensions b and L_2 (see Figure 6).

It can be seen that when a and b are equal to zero, C becomes zero and Eq. 3 is identical with Eq. 1a. Eq. 3 is, therefore, the general equation for the capacity of curb-opening inlets, and Eq. 1a is but a special form for cases with no depression.

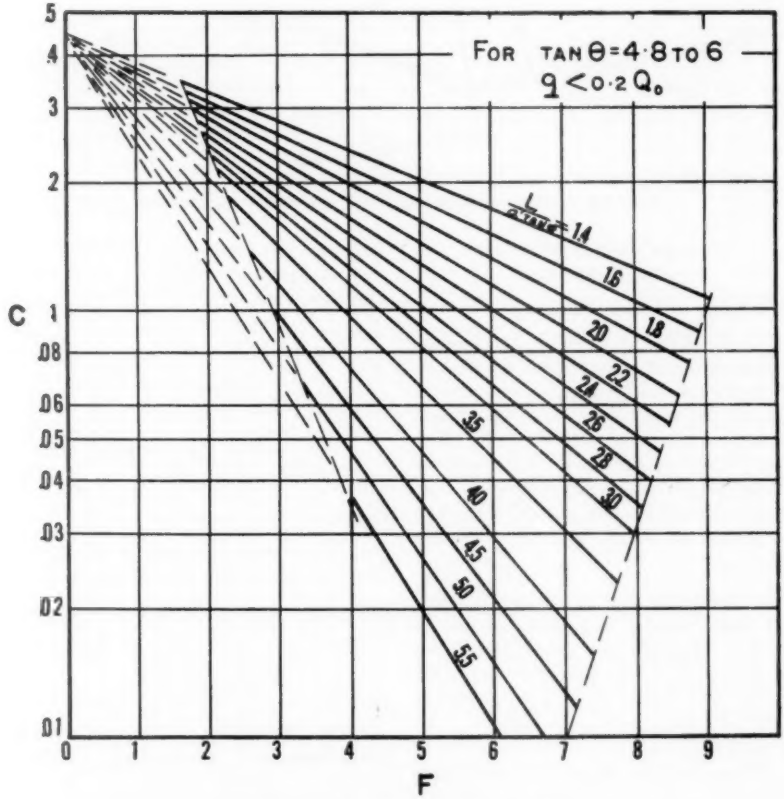

FIGURE 5.—Curves for values of C in Eq. 4a.

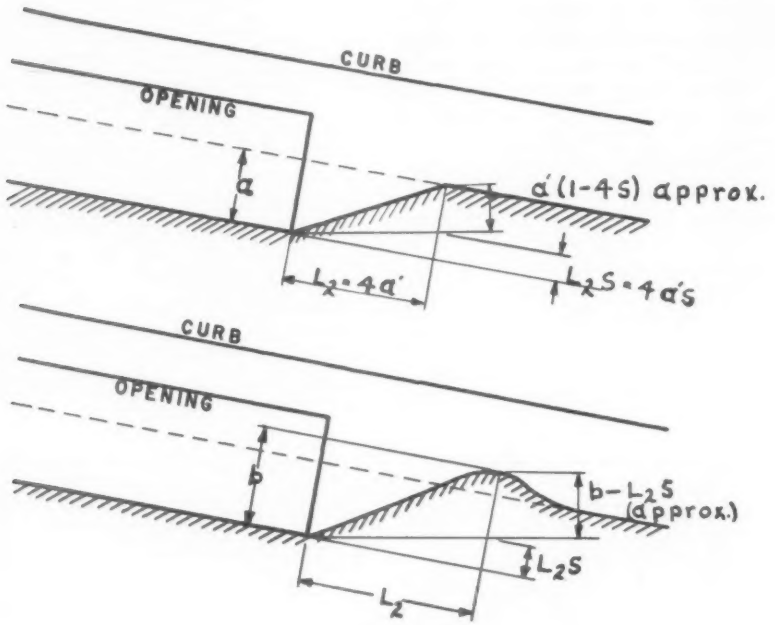

FIGURE 6.—Curb-opening inlets with non-standard depression.

Design Curves for Inlets with Depression

Procedure of Computation

In designing an inlet or checking the performance of a given inlet, the characteristics of the gutter, including the grade, the cross-slope, and the roughness, must be given, and the gutter flow must first be estimated. The values s, θ_0 (in case of a straight cross-slope), n, and Q_0 being known, computation can be performed according to the following procedure:

1. Assuming that Manning's formula for open-channel flow is applicable to gutters, compute, by trials, the depth of gutter flow, y_0, and the mean velocity, v_0. With y_0 and v_0, compute $\left(\frac{v_0^2}{2g} + y_0\right)$.

When the cross-slope is uniform and is defined by $\tan\theta_0$, the value of $\frac{v_0^2}{2g} + y_0$ can be computed directly through the use of Manning's formula to develop the equation

$$\frac{v_0^2}{2g} + y_0 = 0.0202 \frac{(\tan\theta_0)^{1/2}}{(1 + \sec\theta_0)} \left(\frac{\sqrt{s}}{n}\right)^{3/2} Q_0^{1/2} + 1.326 \frac{(1 + \sec\theta_0)^{1/4}}{(\tan\theta_0)^{5/8}} \left(\frac{Q_0}{\frac{\sqrt{s}}{n}}\right)^{3/8} \quad (5)$$

2. Determine the depth of depression, a, and width of depression, w, to be used. Compute $\tan\theta = \frac{w}{\frac{w}{\tan\theta_0} + a}$ and $E\left(= \frac{v^2}{2g} + y\right) = \frac{v_0^2}{2g} + y_0 + a$ (see Eq. 2). Solve Eq. 2 by trials for y. Also compute F, noting that

$$F = \frac{v^2}{g\,y} = 2\left(\frac{E}{y} - 1\right) \quad (6)$$

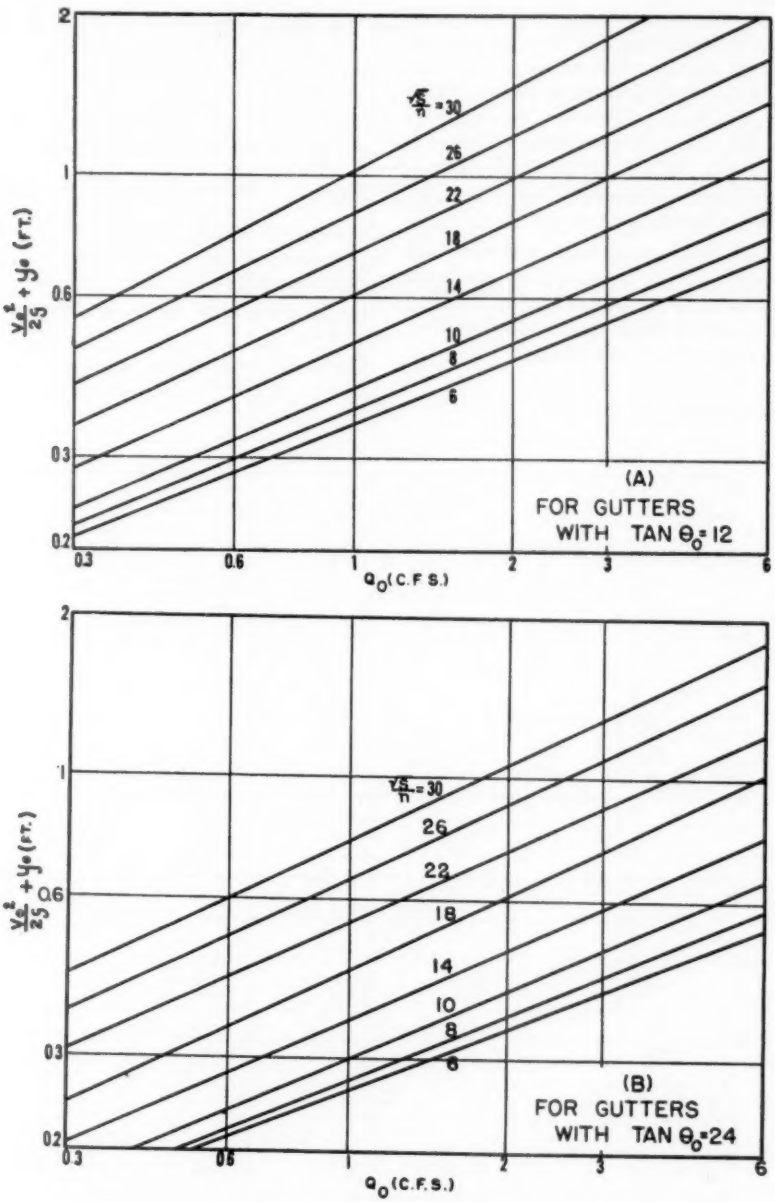

FIGURE 7.—Curves for values of $\frac{v_o^2}{2g} + y_o$.

3. With these computed values of $\tan\theta$ and F, compute the value of C, by using Eq. 4a or Eq. 4b.

4. In case of design, assume a length of opening, L. Compute the capacity, Q, by using the computed values of y and C in Eq. 3. If the carry-over is too large to be desirable, repeat by assuming a larger value of L.

As the computation work outlined above is quite lengthy, it is obviously desirable to employ a graphical method of solution when the number of cases to be investigated is large.

Curves for $\frac{v_0^2}{2g} + y_0$

To obtain the value of $\left(\frac{v_0^2}{2g} + y_0\right)$ quickly, curves similar to Figures 7A and 7B can be prepared for different gutter cross-slopes. Note that on logarithmic paper the curves for different values of $\frac{\sqrt{s}}{n}$ are nearly straight, so that three points usually will be enough to determine each curve. When the gutter cross-slope is uniform and is defined by $\tan\theta_0$, these graphs are constructed by using Eq. 5.

Example.—Construct Figure 7A for $\tan\theta_0 = 12$. Expected Q_0 ranging from 0.3 to 6 c.f.s.

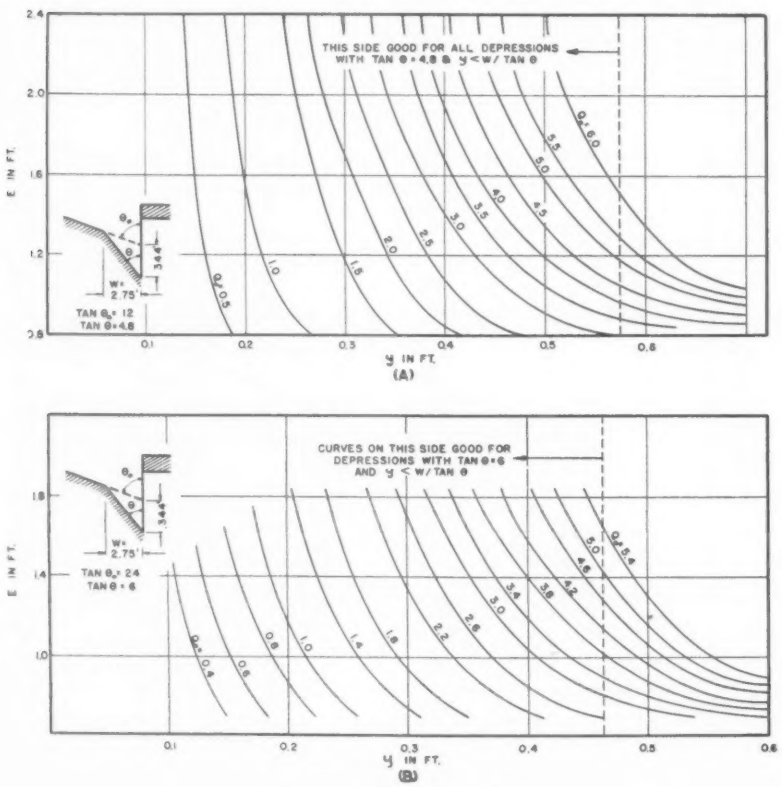

FIGURE 8.—Relation of y to E.

For $\tan\theta_0 = 12$, Eq. 5 becomes

$$\frac{v_0^2}{2g} + y_0 = 0.00538\left(\frac{\sqrt{s}}{n}\right)^{3/2} Q_0^{1/2} + 0.533\left(\frac{Q_0}{\frac{\sqrt{s}}{n}}\right)^{3/8}$$

For the case where

$$\frac{\sqrt{s}}{n} = 10, \quad \left(\frac{\sqrt{s}}{n}\right)^{3/2} = 31.6$$

and

$$\left(\frac{\sqrt{s}}{n}\right)^{3/8} = 2.37.$$

The remaining quantities may then be computed as follows:

Q_0	$0.00538Q_0^{1/2}$	$0.533Q_0^{3/8}$	For $\sqrt{s}/n = 10$		
			1st Term in Eq. 5	2nd Term in Eq. 5	$\frac{v_0^2}{2g} + y_0$
6	0.0132	1.042	0.417	0.440	0.857
1	0.00538	0.533	0.170	0.225	0.395
0.3	0.00292	0.339	0.0923	0.143	0.235

With these computed values, the curve for $\sqrt{s}/n = 10$ in Figure 7A has been constructed. Similarly, lines for other values of $\sqrt{s}/n$ may be determined.

Curves for y

After obtaining $E\left(= \frac{v_0^2}{2g} + y_0 + a\right)$, the next step is to solve for y. Curves similar to Figures 8A and 8B may be constructed for each type of cross-section at the depression to facilitate quick solution. The equation for the curves is

$$E = \frac{Q_0^2}{2g\,A^2} + y$$

Example.—Construct Figure 8A for the depression shown with the figure.

Take the case for $Q_0 = 5$ c.f.s. Then

y	A	$2g\,A^2$	For $Q_0 = 5$		Note:
			$Q_0^2/2g\,A^2$	E	
0.45	0.486	15.20	1.64	2.09	For $y \leq w/\tan\theta$ $(=0.573)$
0.50	0.600	23.15	1.08	1.58	$A = y^2\tan\theta/2$
0.573	0.788	39.9	0.627	1.200	
0.60	0.866	48.3	0.518	1.118	For $y > w/\tan\theta$
0.65	1.035	69.0	0.362	1.012	$A = 1/2a\,w + 1/2(y-a)^2\tan\theta_0$

With these computed values of E, the curve for $Q_0 = 5$ has been determined. Similarly, lines for other values of Q_0 may be constructed.

Curves for C

After obtaining F from Eq. 6, the value of C can be obtained from Figure 5, which has been prepared according to Eqs. 4a and 4b.

Curves for Q

Figure 9 has been prepared according to Eq. 3 to facilitate quick solution for Q.

Example of Computation.—Take the first case listed in Table II. Given $s = 0.005$, $n = 0.0068$, $Q_0 = 2.32$ c.f.s., and $\tan\theta_0 = 12$. Since $\sqrt{s}/n = 10.4$, from Figure 7A $\left(\frac{v_0^2}{2g} + y_0\right) = 0.576$ ft. Since depth of depression, a, $= 0.344$ ft., $E = 0.576 + 0.344 = 0.920$ ft. From Figure 8A, which is applicable to the depression in question, for $Q_0 = 2.32$ c.f.s. and $E = 0.920$ ft., $y = 0.411$ ft. Therefore, $F = 2\left(\frac{E}{y} - 1\right) = 2.48$. With $a' = a = 0.344$ ft., $L = 3.00$ ft., and $\tan\theta = 4.8$, $\frac{L}{a'\tan\theta} = 1.82$. From Figure 5 with $F = 2.48$, $C = 0.269$. From Figure 9 with $y = 0.411$ ft.

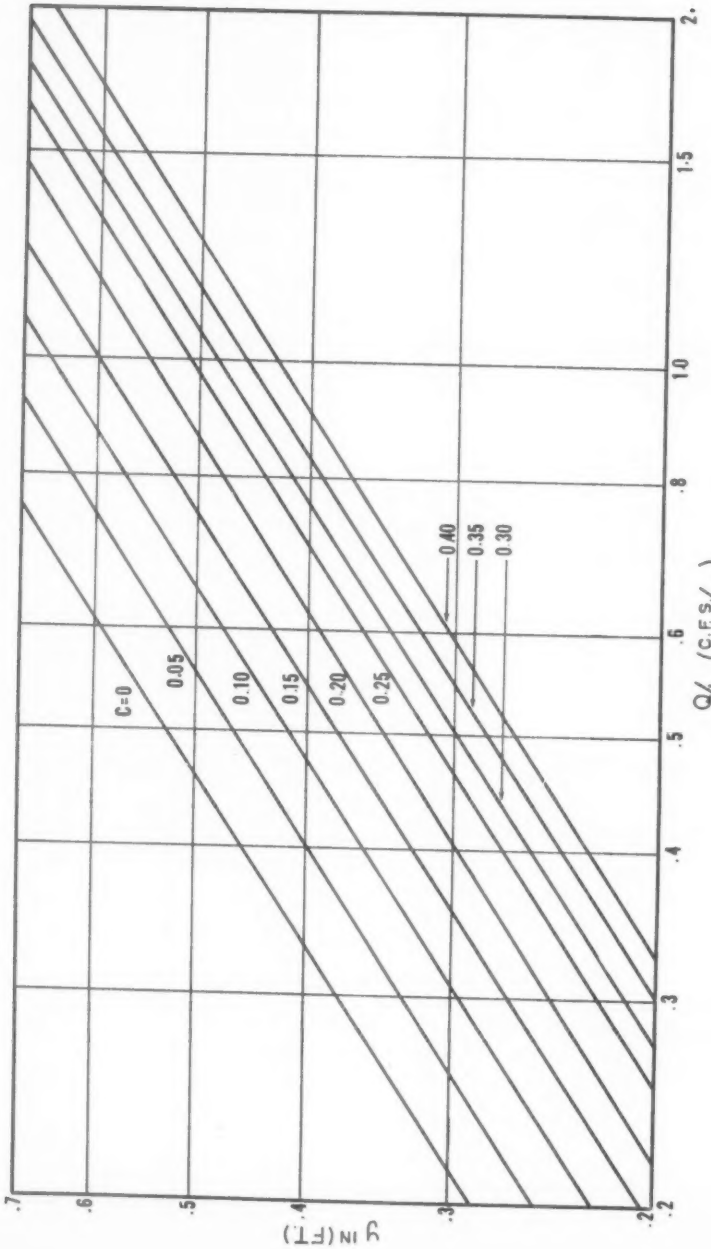

FIGURE 9.—Capacity of curb-opening inlets with depression.

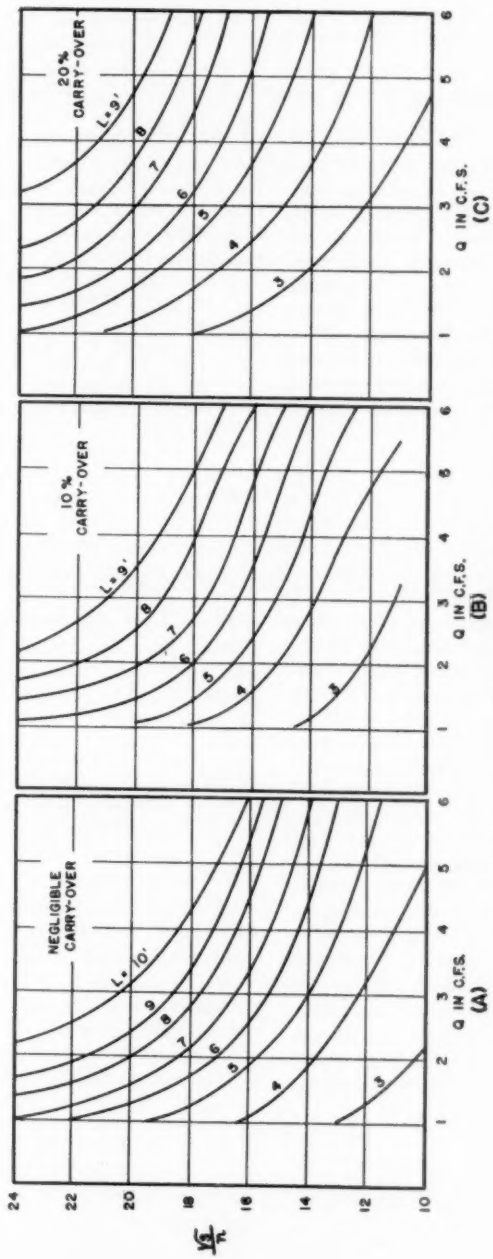

FIGURE 10.—Required length of curb-opening inlet (with 3-in. depression, 2.4-ft. width, and street crown of $\frac{3}{4}$ in. per ft.) for various carry-over factors.

and $C = 0.269$, $\frac{Q}{L} = 0.745$. Therefore, $Q = 0.745 \times 3.00 = 2.24$ c.f.s. Carry-over, $q = 2.32 - 2.24 = 0.08$ c.f.s.

Required Length of Curb Opening

In Figures 10A, 10B, and 10C are shown the computed lengths of curb opening required under different conditions of gutter flow. These curves have been constructed for inlets with depth of depression, $a = 3$ in., width of depression, $w = 2.4$ ft., and street crown = 3/4 in. per ft. ($\tan\theta_0 = 16$). These values have been chosen because they are believed to be representative of field conditions. The curves have been constructed for the purpose of showing approximately the required length of curb opening for the average field condition. As the capacity of an inlet changes with change in the depth of depression and the street crown, each inlet should be investigated independently (see "Example of Computation," above) if the actual field condition is quite different from the average condition as specified above.

Reference

1. Li, W. H., Geyer, J. C., and Benton, G. S., "Hydraulic Behavior of Storm-Water Inlets. I. Flow into Gutter Inlets in a Straight Gutter Without Depression." THIS JOURNAL, **23**, 1, 34 (Jan., 1951).

NEW CLAIMANT AGENCY FOR PRIORITIES

Defense Production Administration Order No. 1, to be released about the time this issue goes to press, provides that the National Production Authority will have claimant agency responsibility in the area of water and sewage matters. The new claimant agency will be known as the Water Resources Division and will have separate water works and sewage works sections.

The new administrative unit is being set up by Harvey S. Howe, who during World War II was administrative assistant to the director, Water Division, Office of War Utilities, and will deal with priorities matters concerning municipal and industrial water and wastes facilities. It is understood that the new agency will coordinate and work closely with the activities of the other government agencies involved, including the Federal Security Agency, the Department of Interior, and the Housing and Home Finance Agency, in the conduct of their work.

Where priority matters cannot be handled through the nearest Department of Commerce field office now acting for the NPA, communications regarding these matters affecting sewage and wastes works may be addressed to the Water Resources Division, National Production Authority, U. S. Department of Commerce, Washington 25, D. C.

Details of new developments and procedures are not available as yet, but will be published in forthcoming issues as they become available.

CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL *

IV. BACTERIAL DECONTAMINATION

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Although the growth of vegetables under sewage irrigation practices does not lead to a higher coliform contamination than when such irrigation is not practiced, the fact that disease producing organisms such as *Salmonella* and *Shigella* species survive only a comparatively short time when applied to growing vegetables, and since even direct application of fecal material to the surface of growing plants appears bacteriologically safe provided the practice is stopped soon enough before harvest, it may still be desirable to reduce the chances for the transmission of disease by some process of decontamination. In addition, raw vegetables of unknown origin and those handled by persons of doubtful cleanliness may require applications of precautionary measures.

Decontamination studies have generally been concerned with methods whereby the bacteria on a vegetable surface could be reduced either by physical removal or by killing. At the same time, the vegetable must not be altered with respect to taste, texture, or edibility. The method of decontamination must be fairly simple, applicable to large-scale as well as small-scale operations, require no great technical skill, utilize relatively cheap materials, be safe in use, and leave no tastes and odors on the treated vegetable. Perhaps of even greater importance, the process must reduce the bacterial contamination to the desired point regardless of the initial concentration of contaminating organisms on the vegetable, individual variations in shape, bruises, cracks, and other irregularities which may exist. In other words, if a particular method is to prove of value in decontamination, every individual vegetable treated by that method should show similar results with respect to bacteriological quality. Uniformity of decontamination is as important as the average degree of decontamination in evaluating the worth of a particular cleaning method. Because the coliform group is more resistant than the disease producing bacteria studied and is composed of the organisms most commonly used for the evaluation of contamination, the results presented are restricted to coliform decontamination.

General Methods

The technique for the evaluation of the coliform concentration on whole or parts of tomatoes utilizing the Waring blender has been used throughout this study. Endo agar and/or lactose and brilliant-green broths were used to evaluate the coliform organism.

The methods of decontamination studied can be divided into the following general groupings:

1. Storage.
2. Washing with plain water.
3. Washing with detergents.
4. Washing with germicidal agents.
5. Use of gases (chlorine and its derivatives).
6. Application of heat.

Unless otherwise indicated, the technique used to study decontamination was as follows: Glass cylinders, 9.5 in. tall and 3 in. in diameter, with ca-

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pacities of 1,200 ml., sterilized by completely filling them with 95 per cent ethanol and allowing them to stand for at least 10 min., were used as washing chambers. The open end of each cylinder was closed by means of a rubber stopper sterilized in boiling water; the ethanol was removed and the cylinders rinsed with cool boiled tap water.

In use, the decontamination solution (generally 500 ml.) was added to the cylinder, the weighed contaminated tomato was added, the cylinder was stoppered and, if desired, the whole was shaken in a machine. In the machine the cylinders were held at an angle of approximately 45 degrees, a reciprocating motion then being applied. This gave the cylinders a horizontal displacement of 1¼ in. and return, 190 times a minute. A vigorous washing was thus obtained, which brought the tomato into intimate contact with the liquor. When a solution containing detergents or germicidal compounds was tested, a series of two or three rapid rinses (200 ml. each) with cooled boiled tap water followed the wash. The decontaminated tomato was transferred directly from the cylinder to a sterile Waring blender for evaluation of the remaining coliform organisms.

Tomatoes grown and contaminated under polluted field conditions and tomatoes purchased at local shops were used. Several methods, including immersion and soaking in sewage, feces, or *E. coli* suspensions, were tried for contaminating tomatoes. In addition, these materials were sprayed on the tomato surfaces and allowed to dry. Methods such as spraying with feces or *E. coli* gave more uniform distribution of contamination.

Experimental Results

Storage

Tomatoes were contaminated by spraying with feces, *E. coli*, or sewage and then drying, and by immersion in sewage for 3 to 4 hr. and then drying. By means of sterile razor blades, sections of skin with areas of 8 sq.cm. were removed for coliform assay. The tomatoes were then stored at 20° C. in large closed desiccators (without desiccant). This prevented further contamination from the air and simulated storage of tomatoes in intimate contact with one another, as would normally take place on a large scale. Relative humidities ranged from 85 to 95 per cent. Controls were also run with uncontaminated fruit.

At daily intervals up to four days, additional skin sections with areas of 8 sq.cm. were cut from the tomatoes and assayed for coliform concentrations. Some condensed results are shown in Table I. The controls continually showed less than 0.3 coliform per sq.cm. The most characteristic feature noted for the contaminated tomatoes is the extreme variability in coliform concentration from day to day. Concentrations may remain practically stationary or increase and/or decrease

TABLE I.—Effect of Storage on Coliforms on Tomato Surfaces (Ranges Expressed in Numbers per Sq. Cm.)

Test Number[1]	Storage Time (days)				
	0	1	2	3	4
C	0.3	0.3	0.3	0.3	0.3
1	3,100 to 56,200	3,100 to 9,400	3 to 56	31 to 1,800	—
2	6 to 31	0.3 to 11	0.5 to 1	1 to 1,400	—
3	0.3 to 2	0.3 to 50	0.3 to 1	0.3 to 560	0.3 to 1,200
4	3 to 560	120 to 3,100	14 to 13,800	44 to 13,800	56 to 18,000

[1] C, controls; 1, sprayed with *E. coli* and dried; 2, sprayed with feces suspension and dried; 3, sprayed with sewage and dried; and 4, immersed in sewage for 3 to 4 hr. and dried.

TABLE II.—Summary of Washing Tomatoes with Three Consecutive Washes of Water Alone

Series	Water	Contaminant	Mode of Wash	Water Temp. (° C.)	No. of Tomatoes Tested	Average Coliforms (no./g.)
A	Soft	*E. coli*	Vigorous	26 to 29	10	23,180
B	Soft	*E. coli*	Vigorous	12 to 14	12	751,000
C	Soft	*E. coli*	Slow	26 to 27	12	112,650
D	Soft	*E. coli*	Slow	12 to 14	8	18,880
E	Soft	Feces	Vigorous	26 to 27	20	40,670
F	Hard	*E. coli*	Vigorous	26 to 27	13	44,650
Average	—	—	—	—	—	—

Series	Over-all Reduction in Coliforms (%)			Average Removal in Each Wash					
				As % of Total Coliforms Removed in All Washes			As % of Coliforms Left After Previous Wash		
	Av.	Max.	Min.	1st	2nd	3rd	1st	2nd	3rd
A	77	95	53	85	11	4	67	26	13
B	56	98	1	82	12	6	47	20	11
C	64	94	23	87	9	4	65	18	8
D	58	96	10	80	13	7	57	16	9
E	74	99	41	85	10	5	65	22	13
F	91	99	62	89	8	3	81	39	25
Average	70	97	32	85	11	5	65	24	13

without pattern. These apparent daily fluctuations may reflect unequal initial distribution of coliform organisms on the tomatoes after contamination, because it is unlikely that multiplication of coliform organisms will take place under these conditions. The high coliform concentrations on the third or fourth day were probably the result of high concentrations on these particular sections. It would appear that simple storage did not result in uniformly decontaminated tomatoes.

Washing with Plain Water

Experiments on washing of laboratory-contaminated tomatoes with plain water were carried out by means of manually shaking the glass cylinder used. A vigorous wash was obtained by rapidly shaking the cylinder in a vertical position 25 times. Slowly shaking the cylinder resulted in a more gentle slow wash.

The detailed results show that the majority of the tomatoes had concentrations of between 10,000 and 100,000 coliforms per gram. The average coliform reductions ranged from 56 to 91 per cent of the original numbers present; the lowest was achieved when cold soft water was used to vigorously wash *E. coli* from tomato surfaces, whereas the highest average removal was found when hard water was used to vigorously wash *E. coli* from tomatoes at room temperature. The over-all reduction was 70 per cent.

The distribution of the over-all removals of coliform organisms after three consecutive washes indicates that approximately 25 per cent of the tomatoes showed better than 90 per cent coliform removal after 3 washes, 50 per cent better than 80 per cent, while 80 per cent showed better than 50 per cent coliform removal. It appears that simple washing does not consistently give good removals of applied coliform organisms. Neither do the results indicate that variation of the washing conditions with respect to the type of water, vigorousness of the wash, or temperature of the water (below lethal temperatures) appreciably influenced the results.

The distribution (Table II) of coliforms in the various washes shows that an average of 80 to 90 per cent of those removed by three washes were found in the first wash. The second wash accounted for only 8 to 13 per cent of those removed, while the last wash contributed little to the removal of coliform organisms. Obviously, as washing progressed the bacteria became increasingly difficult to remove. This was due, it is believed, to variations in the degree of tenacity with which the organisms adhered to the tomato surfaces. If time of agitation were the only factor involved in bacterial removal and the bacteria on a vegetable surface were similar with respect to the ease with which they were removed from that surface, the number of organisms removed would have been proportional to the concentration present at the beginning of the washing period within any given period of washing time, or during any particular wash of a series of washes. The average data show 65 per cent of the original numbers of coliform organisms were removed during the second wash, and finally of those organisms left on the surface after the second wash, only 13 per cent were removed by the third wash. If all the coliforms had been attached to the tomato surface with the same degree of tenacity the percentages removed during each successive wash would have been similar. The regular decrease in these percentages was indicative of rapidly increasing difficulty of removing the remaining surface organisms as washing proceeded.

Contaminating coliform bacteria deposited on tomatoes under natural field conditions may be more or less easily removed by washing than those on laboratory-contaminated fruit. Tomatoes collected from the area receiving continual sewage pollution during the growth of the plants were individually machine washed in 500 ml. of boiled and cooled tap water for 15 min. To simulate the vegetable as it might be served, the rougher stem portion was cut out with a sterile knife after washing and before maceration.

The median values (not washed 80 to 310, washed 230 to 380) indicate that no organisms were removed to any appreciable extent by the washing process. For the laboratory-contaminated tomatoes, the washing was more vigorous and prolonged, and one can only conclude that the tomatoes bacterially contaminated in the laboratory by spraying were more easily decontaminated than field-grown tomatoes. It is conceivable that in order for the bacteria on the surface of field tomatoes to survive they must be well protected, either by closely adhering layers of organic and/or inorganic soil materials, or even partly or completely imbedded in the waxy surface of the fruit. Hence, decontamination of such vegetables would probably be far more difficult to accomplish than that of corresponding laboratory-contaminated vegetables.

Washing with Detergents

As it was impossible to test all detergents, these were grouped into three classes (nonionic, anionic, and cationic) and representative products of different compositions selected. The selection also was influenced by the desire to investigate certain particular compounds used by the U. S. Army Quartermaster for various purposes. The results obtained on 20 different detergents are presented in condensed form.

1. *Nonionic.*—Several series of experiments were made to determine the effect of length and vigorousness of washing in conjunction with detergents and to determine whether increased concentration of detergents in the wash water was of importance. Results show that detergent concentrations in the wash water ranging from 0.1 to 0.5 per cent made no difference in performance. A concentration of 0.1 per cent of these detergents is usual for laundry purposes. In general, the results on coliform organisms remaining

after different methods of washing did not appear to be important. The results for 4 different nonionic detergents with 0.1 per cent concentrations are given in condensed form in Table III. It is evident that these detergents produced no appreciably better results than washing with plain water and that the range of contamination remaining was of the same order of magnitude as when the tomatoes were washed with plain water. Only one out of 84 tomatoes used had a comparatively low coliform count of 50 per gram of tomato.

2. *Anionic.*—As in the previous procedure, the *E. coli*-contaminated tomatoes were machine washed for 15 min. followed by two rinses to remove excess detergent and the contaminated controls washed with plain water to determine any improvement of decontamination by the detergent. From the results (Table III) it appears that, as a group, the addition of anionic detergents to wash waters will not yield tomatoes of better bacteriological quality than those washed in plain water.

Some of the detergents studied produced lower median contamination than plain water, but the range of values of coliform contamination was

TABLE III.—Decontamination of Tomatoes with Various Types of Detergents [1]

Detergent	Contamination	Coliform Organisms Remaining per Gram	
		Median	Range
	(*a*) Nonionic Agents		
Controls	*E. coli* spray	5,400	160 to 17,000
Neutronyx 228	*E. coli* spray	870	370 to 7,700
Tween 80	*E. coli* spray	5,700	2,300 to 23,000
Triton 20	*E. coli* spray	2,800	800 to 36,000
Victawet 12	*E. coli* spray	850	50 to 4,000
	(*b*) Anionic Agents		
Controls	*E. coli* spray	200	43 to 680
Areskap 100	*E. coli* spray	50	13 to 330
Duponol WA	*E. coli* spray	40	1 to 940
MP-189	*E. coli* spray	200	6 to 1,700
Nacconol NR	*E. coli* spray	110	20 to 690
Nytron	*E. coli* spray	270	160 to 700
Santomerse 1	*E. coli* spray	60	19 to 140
Tergitol 7	*E. coli* spray	140	65 to 250
	(*c*) Cationic Agents		
Controls	*E. coli* spray	230	27 to 2,000
Ethyl Cetab	*E. coli* spray	15	3 to 92
Lauryl pyridinium	*E. coli* spray	155	26 to 410
Octab	*E. coli* spray	55	3 to 190
Controls	Sewage irrig.	170	5 to 920
Ammonyx T	Sewage irrig.	15	1 to 590
BTC	Sewage irrig.	430	1 to 7,800
Ceepryn	Sewage irrig.	5	1 to 1,500
Hyamine 1622	Sewage irrig.	700	2 to 1,600
Hyamine M-4	Sewage irrig.	100	1 to 36,000
Roccal	Sewage irrig.	30	1 to 2,000

[1] Concentration, 0.1 per cent of active ingredient; controls washed with plain boiled and cooled tap water.

almost as great as or greater than the controls. The anionic detergents do not appear able to yield consistently decontaminated tomatoes.

3. *Cationic.*—These agents were tested in a manner similar to that for the anionic detergents. Naturally contaminated tomatoes from area A of the sewage irrigation farm were used to evaluate the washing ability of some of the cationic detergents. The majority of the tomatoes used were those with normal stem ends.

The results (Table III) show that certain of the cationic agents (as Ethyl Cetab, Ammonyx T, Ceepryn, and Roccal) gave fairly low median values compared with washing with water alone. Nevertheless, examination of the range of coliform concentrations remaining on the tomatoes in the treated groups indicates that fruit with high concentrations of coliform organisms can survive the action of the cationic agents, so that such treatment is unreliable.

Washing with Germicidal Agents

The germicidal agents most commonly used in modern sanitation are chlorine and its compounds. Their use in water-treatment processes represents the largest-scale attempt at mass sterilization of any product consumed or used by man. The use of chlorine in this respect is due to its effect on bacteria at very low concentrations. It can be applied in larger amounts and, provided the excess is almost completely removed, will enable a treated product to be consumed without undesirable taste or ill effect. It is only natural to expect that chlorine and its compounds could be used to decontaminate vegetables.

1. *Compound Germicidal Rinses.*—Two compound rinses were available which were used as emergency measures during World War II to decontaminate vegetables of unknown or doubtful origin. These are referred to herein as "Compound Rinse ASC–4" and "Compound Rinse RH 968." They were in the form of dry powders, and contained the following compounds: Compound Rinse ASC–4 consisted of azochloramide, the anionic detergent Nacconol NR, and a buffering agent; Compound Rinse RH 968 was made up of dichlordimethylhydanteine, Nacconol NR, and a buffering agent. The recommended concentration of these agents for vegetable decontamination is 3.36 oz. per 5 gal. of water (5.04 grams per liter).

Samples of these compounds showed available chlorine contents of 2.0 per cent for ASC–4 and 6.5 per cent for RH 968 as determined by thiosulfate titration of the iodine liberated from acid potassium iodide. In recommended concentrations this would be 100 and 325 p.p.m. of available chlorine for ASC–4 and RH 968, respectively. The pH of such solutions in soft tap water was 7.9 for ASC–4 and 3.6 for RH 968.

The method of testing the ability of these rinses was the same as for the detergents, *E. coli*-contaminated tomatoes being used.

The condensed results of an agitated machine wash using these two rinses are given in Table IV. The results are compared with unwashed contaminated controls sprayed and dried at the same time in a similar manner. It is apparent that, under these washing conditions, these agents were far superior, as decontaminants, to the detergents previously described. The majority of the treated tomatoes gave less than one coliform per gram of tomato. However, a few tomatoes were able to survive treatment with considerable quantities of contaminants on their surfaces. Thus, treatment by these agents cannot be relied upon to give consistently low results. Furthermore, means for agitation may not always be available or properly operated; therefore, it would be more realistic to test these agents under conditions of soaking. The results of a similar experiment, except that the tomatoes were treated by merely submerging them in

the germicidal rinses for 15 min., show the effects of the absence of agitation. The median contaminations of the treated tomatoes were far greater than one coliform per gram of tomato, the majority having concentrations of more than 200 per gram.

In addition to these compound rinses, attempts were made to test other formulations supplied or suggested. Among those suggested was a formulation considered as a potential all-purpose germicidal rinse for vegetable washing, dishwashing, and other sanitization needs. The rinse was a 0.25 per cent solution of a mixture of sodium phosphate, Nacconol NR, Calgon, sodium carbonate, and chloramine T to give 200 p.p.m. residual chlorine and designated as "1–A."

The effect of soaking vegetables in these rinses is of greater interest than the effect of agitation. Consequently, tests were carried out by immersing individual feces-contaminated tomatoes in 400 ml. of the rinse for periods of 0, 10, 20, 30, 60, and 120 min. The treated tomatoes were then rinsed twice in boiled and cooled tap water and assayed for coliforms. Controls received no treatment. The condensed results are given in Table V. With the exception of the results for 120 min., the median coliform residual concentration of the treated tomatoes gradually decreases after the 10-min. contact period. The higher values of the coliform concentrations of the treated tomatoes are within the values found on the untreated controls. The results would indicate that the use of this compound for decontamination of tomatoes would decrease the average concentration of contaminants on the tomatoes, but fruit with high residual bacterial concentrations could escape. Furthermore, soaking periods greater than 10 min., although beneficial, would not give appreciably improved results.

Another of the compounds tested was designated "I–C" and consisted of a mixture of an organic chlorine compound (chloromelamine), a surface active aryl alkyl sulfonate, and a buffer agent. The sample received indicated an available chlorine content of 9.2 per cent. Because of the insolubility of the material, a solution containing only 370 p.p.m of available chlorine was obtained. The chlorine concentration was on the order of that obtained with the previously described RH 968 and ASC–4. The results show (Table V), except after 15 min., the reduction in the median values of coliform concentrations with increasing length of soaking. In each case high coliform concentrations were found on some of the

TABLE IV.—Effect of Compound Germicidal Rinses[1] on Decontamination

Compound	Coliforms Remaining per Gram	
	Median	Range
(*a*) Machine Washing		
Controls	15,000	12,000 to 17,000
ASC-4	1	1 to 5,400
RH 968	1	1 to 34
(*b*) Soaking		
Controls	36,000	5,100 to 100,000
ASC-4	19–200	1 to 1,600
RH 968	210–2,400	1 to 3,800

[1] Concentration, 5.04 grams per liter.

TABLE V.—Effect of Soaking Tomatoes Contaminated with Feces in Special Formula Rinses

Formula	Soaking Time (min.)	Coliforms Remaining per Gram	
		Median	Range
I-A	0	270	100 to 2,500
	10	45	8 to 90
	20	40	5 to 90
	30	35	1 to 170
	60	22	1 to 340
	120	200	5 to 50,000
I-C	0	7,300	25 to 19,000
	5	150	40 to 8,200
	15	1,700	5 to 2,900
	30	45	1 to 3,400
	60	1	1 to 3

treated tomatoes in each group. Only in the case of the 60-min. soaking period were the results uniformly low. This compound may offer possibilities when long periods of soaking are used. In general, however, the results do not indicate the compound to be vastly superior to other compound germicidal rinses tested.

2. *Free Chlorine Solutions.*—Free chlorine is generally considered to be a much more effective germicidal agent than most of its compounds. For this reason it was desirable to test the action of this agent as a means for decontaminating tomatoes. The previous results with compound germicidal rinses indicated that very high chlorine concentrations probably would be necessary to obtain uniformly low coliform concentrations among a group of contaminated tomatoes.

Chlorine gas was bubbled through ammonia-free distilled water. Dilutions of this chlorine solution were made to give concentrations of approximately 500 and 1,000 p.p.m. of free chlorine. The final concentrations were again checked by titration.

The results (Table VI) show that the majority of the tomatoes were decontaminated to less than one coliform per gram. It is highly interesting to note that, just as in the case of the germicidal rinses, comparatively high residual coliform concentrations can be found on tomatoes receiving dosages of chlorine on the order of 1,000 p.p.m. The protection afforded the bacteria was probably due to organic material, which was dried on the surface with the organisms. Naturally contaminated tomatoes have even greater resistance to decontamination because of cracks and crevices and because bacteria are present which can survive extremely adverse conditions of sunlight, heat, and desiccation. Similar protective mechanisms are probably operative in the prevention of consistent decontamination of tomatoes with strong chlorine solutions.

Use of Gases

The presence of a water-repellent waxy layer on the surfaces of vegetables may prevent proper penetration of surface-active or germicidal compounds to the well-protected organisms. The penetration to these deeper or protected portions may be more readily accomplished by means of a killing gas.

As nitrogen trichloride in the gaseous

TABLE VI.—Decontamination with Various Gases

Treatment	Coliform Organisms Remaining per Gram		Remarks
	Median	Range	
Cl_2 solution:			
0 p.p.m	17,000	4,000 to 50,000	*E. coli* sprayed and dried
528 p.p.m.	1	1 to 60	Machine washed, 15 min.
1,028 p.p.m.	190	1 to 17,000	Hand washed, 15 min.
1,028 p.p.m.	1	1 to 17,000	Soaked, 30 min.
Controls	40	4 to 4,900	Feces sprayed and dried
NCl_3 gas	19	1 to 43,000	Gas for 1 hr.
Controls	39	3 to 96	Feces sprayed and dried
t-butyl hypochlorite	1	1 to 250	Gas 1 hr. (av. 3.2 p.p.m.)
Controls	130	2 to 320	Feces sprayed and dried
Cl_2 gas:			
30 p.p.m.	1	1 to 23	Gas 1 hr.
110 p.p.m.	1	1	Gas 1 hr.
350 p.p.m.	1	1	Gas 1 hr.

state has been successfully used commercially to delay fruit rotting, it was tested against bacterially-contaminated vegetables.

1. *Nitrogen Trichloride.*—This compound in a dilution of air was produced by bubbling air through a solution of ammonium chloride being subjected to electrolysis. The design for the NCl_3 generator was provided by the Wallace and Tiernan Co., Inc., and was used with slight modifications. The generator consisted of a 30 per cent solution of ammonium chloride, into which were immersed two carbon electrodes connected to a 6-v. rectifier. The current could be varied up to 600 milliamperes. A metered stream of moist air was bubbled into the solution when the current was applied resulting in mixing of the products of electrolysis. Provision was made to dilute the NCl_3 bearing air with clean air. The NCl_3 content of the air stream was measured by collecting a measured portion in a gas burette containing ortho-tolidine. Repeated inversions of the burette absorbed the NCl_3 into the solution, producing the characteristic yellow color, which could be compared against chlorine standards. The NCl_3 concentration of the air was then calculated in terms of chlorine. Feces-contaminated tomatoes were used to test the efficiency of these gases. Five contaminated tomatoes were placed in a 2-l. cylinder, one above the other. The gas was passed through a tube to the bottom of the cylinder and then upward around the tomatoes. The gas was sampled just before, halfway through, and at the end of a run. After treatment for 1 hr., pure air was delivered to the vegetables for 10 min. before they were removed for assay. A gas flow of 600 ml. of air per minute containing 1.4 to 1.7 mg. NCl_3 (as Cl_2) per liter was used to treat tomatoes for 1 hr. This amount was produced by using a current of 600 milliamperes.

The results (Table VI) show that the treated tomatoes as a group are not appreciably better than the untreated controls. It must be pointed out that the NCl_3 concentration used was considerably higher than that employed for the prevention of fruit spoilage.

2. *t-Butyl Hypochlorite.*—This was obtained as a solution from the Wallace and Tiernan Co., Inc. A metered stream of air (20 ml. per min.) was bubbled through a portion of the liquid and was mixed with clean air delivered at the rate of 500 ml. per min. This gave a concentration of 5.5 p.p.m. t-butyl hypochlorite (as Cl_2) at the beginning of treatment and 0.9 p.p.m. at the end of one hour, or an average of 3.2 p.p.m. The available chlorine content of the air was measured in the same manner as in the case of NCl_3. Feces-contaminated tomatoes were treated in the same manner.

The results obtained (Table VI) show that although the median residual contamination of the treated tomatoes was lower, the range of values was essentially the same as for the controls.

3. *Chlorine.*—Higher concentrations of available chlorine could be obtained by using gaseous chlorine diluted with air. The chlorine content was measured in the same manner as for the preceding gases, except that acid potassium iodide was substituted in the gas burette and the freed iodine was titrated with standard sodium thiosulfate. The feces-contaminated tomatoes were treated in the same manner as above. Three concentrations of chlorine were used in an air stream of between 500 and 600 ml. per min. These were 30, 110 and 350 p.p.m. Cl_2 and were delivered to the tomatoes for 1 hr.

The condensed results, given in Table VI, show that for chlorine concentrations of 110 and 350 mg. per liter the tomatoes were consistently decontaminated to less than one coliform per gram. However, these concentrations caused a bleaching of the tomatoes in the areas about the stem end. This was most severe at the higher concentrations of chlorine. Apparently, the more waxy smooth skin

was not sufficiently penetrated to cause bleaching.

It appears that a concentration of between 30 and 100 p.p.m. Cl_2 for 1 hr. is required to effect coliform decontamination of these vegetables. Whether these concentrations could be handled safely in large-scale units is open to question, without considering the time required.

Application of Heat

It is apparent that the bacteria on the surface of tomatoes may be so well protected by deposited material or by imbedding in the waxy surface that detergents and germicidal rinses are not able to reduce the contaminants to consistently low values. Obviously, a means whereby the protection can be penetrated and the organisms killed *in situ* would be a most effective method for decontamination. The application of heat is such a method, the action of which could be had without the necessity of the penetration of agents through the waxy skin of the fruit, into cracks or crevices or through protecting layers of debris. Too high a temperature for too long a period would result in a wilted or cooked product.

Groups of five tomatoes were immersed singly in water at a given temperature for a specified time. A wire basket was used to hold the tomatoes completely immersed. The container was sterilized in boiling water for 5 min. before each determination. After treatment, the tomatoes and baskets were immersed in cool tap water (boiled and cooled to room temperature) for 2 to 3 min. and analysis was made for coliforms, using the whole tomato for assaying.

The tomatoes used in these experiments were from areas of the sewage irrigation farm experimental plots which were receiving or had received sewage contamination. Most of the tomatoes used possessed abnormal stem ends exhibiting cracks and crevices, which would afford protection for bacteria against external conditions as well as against other decontaminating agents.

TABLE VII.—Decontamination of Tomatoes By Dipping in Warm Water for 5 Min.

Temp. (° C.)	Coliforms Remaining per Gram	
	Median	Range
Controls	77	1 to 180
50	76	1 to 4,400
60	1	1
70	1	1

The temperatures of particular interest studied were 50°, 60°, and 70° C. with immersion for 5 min. Higher temperatures were found to scald the fruit and loosen the skin on immersions of a few seconds. Even at 70° C. this effect was found in 5 min. At 60° C. the tomato skins were normal except that some loosening occurred on very ripe fruit. Longer periods of immersion increased the effect. At 50° C. the skins showed no signs of peeling. Controls were assayed without treatment.

The condensed results of warm-water decontamination (Table VII) show that a temperature of 50° C. for a 5-min. immersion period was not effective in decontamination. At 60° and 70° C., low median values for the residual coliform contamination were obtained. In contrast to most of the other decontamination techniques studied, immersion at these temperatures gave consistently low coliform values for the whole group of tomatoes. A temperature of 60° C. was as effective as 70° C. for decontamination, and peeling did not occur within the time needed for decontamination (5 min.).

Discussion

The effectiveness of a particular vegetable decontamination process must be judged on the basis of two criteria —average reduction or lowest possible average level of residual concentration of contaminating organisms which result from a particular process, and the uniformity of the decontamination. The two are of equal importance. If

the majority of a group of vegetables possesses easily removable organisms on the surfaces, the average reduction by a particular decontamination process may be high, but a minority containing organisms removable with difficulty due to variations of surface, growth, etc., may be untouched by that process. Although it may be argued that the sanitary quality of the group as a whole will be improved, methods of decontamination should be sought which can be more securely used for vegetable sanitization. Such methods should not only reduce the average contamination of a group, but also should do so uniformly. The range of the residual contamination of the group as a whole should be comparatively narrow. The results of decontamination studies, as well as relative evaluation of the effectiveness of various decontamination methods, should be considered in the light of this argument.

The various decontamination methods studied have been presented in the order of increasing efficiency of treatment. Storage is dependent upon the natural death rate of the test organisms at ordinary temperatures. Washing with plain water or detergents of the nonionic or anionic types is a technique which relies on the physical removal of the bacteria from the contaminated surface. Cationic agents have a bactericidal property as well as a detergent action. The activity of germicidal rinses and chlorine solutions and gases is based on the bactericidal properties of chlorine and its derivatives. Decontamination by heat is dependent upon the rapid death rate of microorganisms at elevated temperatures.

Storage of tomatoes did not appear to offer promise as a means of effectively and consistently reducing the coliform concentration on tomato surfaces. The experiments show that spraying with *E. coli* or feces suspensions indicated higher coliform contamination than unsprayed controls at least 11 days after spraying. If these organisms were able to survive the adverse conditions in the field, at least an equal resistance under storage conditions would be expected where relative humidities are higher, temperature variations are less, and sunlight is absent. Storage for one or two weeks with some sort of refrigeration to prevent spoilage would increase survival at reduced temperatures. Dependence on the natural death rate of coliform organisms under ordinary storage conditions does not appear to offer an effective means of decontamination.

The results of the work on washing with plain water indicate that for most of the laboratory-contaminated tomatoes the majority of the contaminating organisms were removed in the first washing operation. With successive washes the bacteria became increasingly difficult to remove. The conditions of the washing process, such as water temperature (20° to 30° C.), hardness, or the degree of agitation, were not important factors. However, washing of field-contaminated tomatoes with water was practically worthless in removing surface contamination. Bacteria on the surface of tomatoes contaminated in the field are tenaciously attached. As laboratory-contaminated tomatoes are more easily cleaned than field-grown fruit, the former will give results which cannot be directly applied to naturally contaminated tomatoes, hence a completely effective method of decontamination may be found for laboratory-contaminated tomatoes which will not be reliable when used on natural fruit. Similarly, when a particular decontamination process is found to be ineffective against the laboratory-contaminated fruit it cannot be expected to be better for naturally contaminated tomatoes. Therefore, the use of the laboratory-contaminated products when naturally contaminated fruit are not available is of value only for screening various decontamination processes.

Various types of detergents might

prove of value in removing surface contaminants that resist plain water. The property of surface tension reduction was considered an asset toward this end. Any germicidal activity possessed by some detergents, the cationic types in particular, would be expected to increase the effectiveness of the agent. The tests were usually run at concentrations of 0.1 per cent active ingredient (1,000 p.p.m.). Several detergents studied showed the greatest reductions of surface tension in concentrations up to 0.01 to 0.1 per cent in water. Higher concentrations did not greatly increase this effect. Several of the cationics tested are sold as commercial sanitizers for use in concentrations between 100 and 1,000 p.p.m. It has been shown that the concentrations required to kill enteric bacteria may vary with the detergent and environmental conditions, but are generally less than 0.1 per cent (1). In general, the results using detergents of the anionic, nonionic, and cationic types did not indicate greatly increased effectiveness over plain water. Although some of the agents tested, particularly the cationic detergents such as Ethyl Cetab, Ceepryn, or Ammonyx T, gave comparatively low average residual coliform concentrations on treated tomatoes; concentrations survived treatment which were equal in range to those on untreated tomatoes.

The results on decontamination with chlorine and its compounds in solution indicate that when available concentrations of 100 to 1,000 p.p.m. were applied the average coliform concentration could be reduced to less than one per gram of tomato. However, high coliform counts, on the order of those obtained with plain water washes may result. It is striking that uniformly effective coliform reduction by washing in plain water with detergents, or even in strongly bactericidal solutions of chlorine, was extremely difficult. It appears that certain of the bacteria are so tenaciously attached to the vegetable surface, protected by adherent layers of debris, or even imbedded in the wax film of the fruit surface, that physical removal or penetration of disinfectants becomes extremely difficult. The waxy nature of the fruit surface also makes wetting more difficult.

More effective results might be obtained with chlorine or its compounds in the gaseous state, as penetration would not be so dependent upon wetting of the surface of the vegetable. The results with NCl_3 indicate that effective bacterial decontamination cannot be obtained with concentrations used to treat fruit for spoilage control. Indeed, treatments as high as 30 to 100 mg. per liter of gaseous chlorine were required to effectively decontaminate feces-contaminated tomatoes. Disadvantages in the use of a gas such as chlorine are the bleaching effect on the vegetables, the possibility of imparting an undesirable taste to the vegetable, and the difficulty of safely handling such a dangerous gas under field conditions.

Elevated temperatures increase the death rate of bacteria. At the same time, heat can penetrate and act on bacteria on the surface of a vegetable regardless of the presence of cracks and crevices, protective layers of organic material, or the position of the organisms with relation to the wax of the outer layer. A disadvantage of this method is that the temperature required for effective decontamination may be so high that scalded or partly cooked vegetables may result. A temperature of 60° C. for 5 min. was extremely effective for decontamination, resulting in uniformly low coliform concentrations of less than one per gram. At the same time, this treatment in no way affected the texture or appearance of the skin. In this respect it is interesting to note that Mills, Bartlett, and Kessel (2) have reported that submergence of fruits and vegetables in boiling water for 10 to 30 sec. was the only method found which would uniformly kill all pathogenic bacteria, protozoan cysts, and helminth eggs on

contaminated raw foods and render them safe.

Conclusions

The experimentation on the coliform decontamination of raw tomatoes, which had either been grown on polluted soils or contaminated in the laboratory by spraying on and drying suspensions of *E. coli* or feces, has led to the following conclusions:

1. The natural death rate of these bacteria under ordinary storage conditions of temperature and relative humidity is not rapid enough to insure adequate decontamination.

2. Agitated washing of laboratory-contaminated vegetables with plain water removes the majority of the contaminants, but not coliforms deposited on tomatoes grown on polluted soil. The greater adherence and protection of the organisms on the surface is indicative of the protected state on the vegetable surface.

3. The use of agitated anionic, nonionic, and cationic detergent washes does not, as a rule, give better results than plain water. Many cationic detergents have bactericidal properties. Some of these agents are fairly effective but not consistent decontaminating agents.

4. Chlorine and its compounds in high concentration in solution are fairly good coliform decontaminants, but these agents may not be entirely effective if the bacteria are well protected in cracks, crevices, bruises, and deposits of material on the skin surface.

5. Chlorine gas is a good decontaminating agent, but causes bleaching. The concentrations of chlorine required are from 30 to 100 mg. per liter of air. Nitrogen trichloride and t-butyl hypochlorite are not so effective in the concentrations normally used.

6. The only effective means for consistently obtaining a low coliform residual without changing the character of the fruit is to utilize heat. A temperature of 60° C. for 5 min. resulted in a low contamination, yet did not alter the quality of the tomatoes.

Summary

Studies on coliform decontamination of raw tomatoes grown on sewage polluted soils, or sprayed with *E. coli* or feces, show that the natural death rate of these bacteria under ordinary storage conditions is slow and does not insure adequate decontamination. Vigorous washing for 15 min. with plain water removes most of the sprayed-on contaminants, but does not remove coliforms from tomatoes grown on polluted soil. In general, vigorous washing with anionic, nonionic, and cationic detergents is not materially better than washing with plain water. Chlorine and its compounds in high concentration in solution do not remove organisms protected by dirt, or in cracks, crevices, or bruises. Chlorine gas is a good decontaminating agent, but causes bleaching in the concentrations required. Nitrogen trichloride and t-butyl hypochlorite are not effective in the concentrations normally used for fruit spoilage control. The most effective method for consistently obtaining a low coliform residual, without affecting the appearance and condition of the vegetables, is soaking them in water at a temperature of 60° C. for 5 min.

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Industrial Wastes

1950 INDUSTRIAL WASTES FORUM *

R. D. Hoak, *Leader*

Senior Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

Pretreatment for Recovery of Usable Products

Chairman Hoak:—Among many who are not well informed about the difficulty of recovering useful products from wastes, the misconception is widespread that there are available a great many valuable materials that are being discharged willy-nilly, simply because no one has taken the time or the trouble to attempt their recovery.

Most of us think that is a false impression, except in unusual cases. Although there are certain instances in which useful recoveries can be made, in the great majority of cases it is not possible to recover anything of very great value from industrial wastes.

Stuart E. Coburn, Metcalf and Eddy, Consulting Engineers, Boston, Mass.:—During the first part of the Twentieth Century, stream pollution was a problem concerning sanitary engineers. Today, it is rapidly becoming a problem for chemists or chemical engineers where treatment of industrial wastes is concerned.

Wastes treatment is highly specialized, and each industry has its own problems to solve. Methods common to treatment of sewage or wastes—for example, sedimentation, thickening, chemical precipitation, sludge filtration—may be used in reducing stream pollution.

Sludge produced by these processes was disposed of in the easiest possible manner, such as lagoons, drying on sludge beds, vacuum filtration, or other methods, as long as the pollutional load was removed from the stream.

Some potentially valuable constituents in wastes, formerly discarded, are now being recovered in certain instances. Studies have been made and methods developed for removing and recovering these constituents, which may return a profit on the recovery or at least go a long way toward the cost of construction and operation of wastes treatment plants.

Some of the problems on which considerable work has been done are recovery of distillery and brewing slop, paper and pulp solids, yeast, chromates in the plating industry, slaughterhouse and tannery wastes, and caustic from cotton mercerizing wastes.

Wool scouring wastes containing mixed wool waxes are treated for the recovery of by-products. Besides the large tonnages of acid degras used in the cordage industry, for stuffing leather, or in the manufacture of lubricants, smaller but gradually increasing quantities are now being used in the manufacture of lanolin, paints and paint dryers, soaps, rust preventives, waterproofing, wetting agents, emulsifiers, cosmetics, cholesterol, and other such materials. In the wool scouring industry, however, where there are 80,000,000 lb. of greases that are recoverable, only a very small amount of the wool fat is being recovered. If all that grease were taken out of the waste, the grease would have to be sold at a price that would not pay the operating cost.

* From transcript, 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Washington, D. C.; October 9–12, 1950.

What is the effect of the operation? What is the economic situation going to be? Is the company going to segregate profits from waste recovery? We are dealing with another portion of the plant operation. Is the stream pollution aspect going to get very far?

I am just raising a few questions to get a discussion started. I hope somebody will take the other side of the question. It is not all profit, but how can we further develop recovery today?

T. R. Haseltine, Partner, The Chester Engineers, Pittsburgh, Pa.:—Mr. Coburn asked somebody to take the bright side of the discussion on by-products recovery, but I am not sure there is a bright side.

There has long been too much stress placed upon by-product recovery and too little on waste treatment. Too many published articles have painted glowing pictures of the by-products recoverable from waste treatment and too many industries have used their inability to develop profitable by-products as an excuse for delaying waste treatment. Recent laws of many, if not most, states now make waste treatment compulsory. By-product recovery is still optional. Whether or not it should be incorporated in a waste treatment program should be decided solely on the basis of cold economic facts, not on the dreams of some theoretical chemist, or the visions of some humanitarian or philanthropist.

Today we hear much about soil conservation and soil rehabilitation. The manufacture and use of commercial fertilizers have expanded enormously. Some agriculturists are stressing the special benefits to be gained from the use of organic instead of chemical fertilizers. Domestic sewage is a widely distributed source of organic matter. Good fertilizer can and is being made from it. To the uninitiated, it might seem obvious that provisions for the manufacture of fertilizer as a by-product of sewage treatment should be universally adopted. However, a recent survey of 138 sewage treatment plants in New York, New Jersey, Pennsylvania, Ohio, Maryland, Virginia and West Virginia showed that at only 24 plants was any fertilizer value realized from the sewage. Of those 24 plants, one large one made commercial fertilizer, two small ones disposed of wet sludge by plowing it into fields, and the other 21 either sold partially dried sludge locally, or disposed of it on municipally owned parks, cemeteries, etc. Careful studies in connection with numerous new sewage treatment projects show that it is frequently impossible to justify fertilizer production economically, despite the fact that some communities find such production to be warranted.

All local, as well as other factors must be considered in deciding whether or not by-product recovery is warranted. The mere fact that one industrial establishment has found the recovery of a certain by-product to be worth-while is no proof that a similar industry, in a different location, would find similar by-product recovery economically justified.

Ferrous sulfate or other iron compounds and reclaimed acid appear to be such logical and obvious by-products of the treatment of spent metallurgical pickling liquors that at least 45 different process patents have been issued for their recovery. A few steel mills do find the recovery of one or more of these by-products to be warranted. However, in general, the situation is much the same as it is in the case of fertilizer recovery from sanitary sewage. The cost of installing and operating the processes is too great, and the value of the by-products is too low, to justify the recovery. Fifteen years ago the Armco Steel Corporation at Butler, Pa., attempted recovery of copperas and acid from their pickle liquors on a large scale. However, the operations were soon discontinued for economic reasons, despite the fact that those mills now purchase 30 tons of lime a day to treat 1 m.g.d. of pickling wastes.

Three men on each turn, plus a foreman on the day shift, are required to operate the neutralization plant; the treated wastes must be pumped 4,000 ft. against a 300-ft. head to lagoons. The present lagoon, their fifth, is 20 ft. deep and covers 18 acres. Its expected life is only 6 to 7 years.

It is a generally accepted fact that if more steel mills attempted to recover copperas from their pickling wastes the market for that by-product would be so glutted that recovery would no longer be justifiable, even at those few plants that now find it warranted.

A somewhat similar situation prevails in several other industrial waste fields. For example, distillers' light and dark grains are logical and obvious by-products of distillery waste treatment. During World War II the Government financed a number of installations of evaporators, dryers, boilers, etc., required for recovery of these by-products. One such installation that we engineered for a distillery having a capacity of 87,000 g.p.d. of beer has been completely dismantled. I gather from the literature that even the big distillers are going more and more to anaerobic digestion processes instead of by-product feed recovery. I presume the market for distillers' grains has been glutted.

Spent tans from vegetable tanneries normally account for only about 5 per cent of the volume, but 25 per cent of the total solids and 50 per cent of the B.O.D. of the tannery wastes. Some tanneries concentrate these tans to a syrup containing 50 per cent solids by means of multiple-effect evaporators; a few further dehydrate this syrup on dryers to a commercially dry powder. The syrup or the powder is sold to concerns that utilize it in preparing water treatment compounds. In January, 1949, the National Aluminate Corporation, one of the two principal purchasers of spent tan concentrates, advised us as follows:

"The consumption of liquid spent tannin has been decreasing, and we believe will continue to decrease, in the water treatment field. With freight rates increasing . . . and with the improvement of the art of water treatment in general, the use of liquid compounds is rapidly diminishing.

"The powdered spent tannin at the present time has chiefly low cost as its foremost advantage. There is, however, a limit to the amount of this material that can be used in water treatment. With those concerns already drying or that will be drying in the near future, the limit of the market has, we believe, been approached. You must also consider that a good many other industries are considering organic extracts, and consequently the available supply of many different types of organic materials is becoming tremendous."

The Armour Leather Company at Williamsport, Pa., has converted one-half to one-third of its spent tans to the syrup for the past 14 years. They advise that the price now received for that concentrate is insufficient to meet the costs of steam and operating attendance, let alone bear any portion of the fixed charges.

It was previously mentioned that Armco Steel Company at Butler, Pa., has found lime treatment of all pickling wastes to be more economical than the pretreatment of some or all of those wastes for the recovery of acid and copperas. This is generally true for most steel mills. However, the disposal of the large volumes of calcium sulfate-ferrous hydrate sludge resulting from the lime treatment constitutes a real problem. In 1938, the Sharon Steel Corporation started pilot-plant studies of the Ferron process for converting that sludge to bricks, blocks, slabs, and sheets that could be used as interior building materials. World War II interrupted the studies, but they were resumed for a while after the war before being finally discontinued. Even if all technical manufacturing problems were overcome, the marketing of such a highly competitive product would impose some real problems. Few steel mills produce enough sludge to permit the manufacture of Ferron products in sufficient quantities to justify a national advertising and

sales campaign. Without such a campaign, the products could only be disposed of in a local market where demand, if any, would be highly fluctuating. I have always been intrigued with the idea that in a steel center such as Pittsburgh some enterprising concern might undertake the collection of sludge from several mills and the conversion of that waste to building materials in a single large plant with sufficient capacity to justify a national sales organization.

The dairy industry has a surplus milk problem, as well as a waste treatment problem. At present, much of the surplus milk is separated and the cream, along with a relatively small portion of the skim, is converted to ice cream. Ice cream is widely advertised, but the residual skim milk constitutes a problem that is all too frequently solved by dumping it down the nearest stream or sewer. Numerous by-products are possible, of which cottage cheese is perhaps the simplest. Unfortunately, the demand for cottage cheese is too small to be of much help. However, I recall reading that, although the per capita consumption of cottage cheese was only 2 lb. per year in the United States as a whole, it was 6 lb. in California. Cottage cheese is rarely advertised. Might not an intensive sales campaign increase its consumption to the point where its production would be of real aid to the dairy industry in solving some of its waste treatment problems?

The foregoing discussion should illustrate the importance of considering the demand for and the marketing of by-products, as well as the technical problems of their manufacture, when deciding whether or not by-product recovery should be included in waste treatment programs. The forecasting of future demands and market conditions is beyond the ability of many engineers, including the speaker. The necessity for such forecasts can be avoided if the industry is fortunate enough to find a by-product of waste treatment that can be used in its own plant. In looking for such a by-product do not overlook the water itself. We recently made surveys for a metal fabricating company that purchased 1.5 m.g.d. of municipal water and paid an annual water bill of $24,000. They were faced with the added cost of about $18,000 a year for partially treating their wastes to make them admissible to the proposed municipal sewage treatment plant and the further payment of at least $22,000 a year in sewer service charges. Our survey indicated that, by installing certain water conservation, as well as the necessary pretreatment facilities, they could cut their total water supply and waste treatment and disposal costs to $31,000 a year, a saving of $33,000 a year due to water re-use.

The Butler works of Armco Steel Corporation has long felt the need for a better and more abundant water supply. Recently the Sanitary Water Board of Pennsylvania ordered them to cease pollution of the receiving stream with oil and scale discharged in some 9 m.g.d. of cooling water. At present, Armco is operating a pilot plant to determine whether or not those wastes can be so treated with lime and spent pickle liquor as to not only make them suitable for discharge to the stream, but also suitable for re-use and thus solve their water supply problem.

One of the most interesting examples encountered of by-product recovery and re-use within an industry is in the operations of a chemical and dye manufacturer. This concern manufactures ultramarine and soluble dyes of the triphenylmethane type, as well as various other products. As a result of ultramarine manufacture, a 10 per cent solution of sodium sulfate is produced. Rather than discharge this to a sewer, they undertook the manufacture of "blanc fixe," a relatively pure barium sulfate. Its manufacture utilized the waste sodium sulfate to precipitate the "blanc fixe" from a barium sulfide solution formed by leaching

black ash. The operation has proved so profitable that the company now purchases Glauber salts to augment the supply of sodium sulfate that originally went to waste.

However, the "blanc fixe" process itself produces another waste containing about 3 per cent sodium sulfide. Dehydration operations in connection with soluble dye manufacture produces a 40 per cent sulfuric acid solution. These two wastes are combined under controlled conditions to liberate H_2S, which is then dissolved in ammonium hydroxide to produce another by-product of commercial value—ammonium sulfide.

Although these operations utilize by-products that would otherwise go to waste, they do not eliminate the need for waste treatment. There still remains 300,000 g.p.d. of wastes containing 700 p.p.m. of sulfides and 1,000 p.p.m. of sulfates (with a pH of about 11), which must be disposed of. The company is now experimenting with biological treatment of these wastes and meeting with considerable success.

Seldom, if ever, is by-product recovery a substitute for waste treatment. It may reduce either or both the volume and composition of the wastes to be treated, or it may completely change the character of the wastes to be treated, but it does not eliminate the need for waste treatment. For example, cottage cheese manufacture reduces the amount of skim milk to be disposed of by a dairy, but results in the production of a whey that requires treatment. Skim milk has a 5-day B.O.D. of about 73,000 p.p.m., whereas the whey has a B.O.D. of only 30,000 p.p.m. Thus, recovery of cottage cheese effects a 60 per cent reduction in the B.O.D. Further treatment is still necessary.

This brings up the final point to be emphasized in connection with by-product recovery—that although the value of a given by-product may be less than its cost of production and marketing, its recovery may still be justified, if, by such recovery, the cost of residual waste treatment is reduced sufficiently to offset that difference in costs. To illustrate this point, the case is cited of a dairy that, at times, acts only as a recovery station, but is equipped to produce cottage cheese, ice cream mix, sweetened or unsweetened condensed milk, and dried milk. At present, it is converting all surplus skim milk to powder at a cost of about 9¢ per pound, despite the fact that this product can be sold for an average of only 7¢ per pound. An average of about 64,000 lb. of skim milk are evaporated and powdered daily at a loss of approximately $100 per day. However, by producing this by-product, the B.O.D. of the wastes are reduced about 4,500 lb. per day. This same dairy is investing $80,000 to treat wastes having a B.O.D. of only 600 lb. per day. If the same ratio of plant cost to B.O.D. load held the $100-a-day operating loss, it would effect a saving of $600,000 in capital outlay for waste treatment facilities. No doubt the operating loss due to by-product recovery is economically justified in that particular case, although some other dairy, not equipped to produce powdered milk, could not afford to install and operate such equipment at a loss just to reduce waste equipment costs. This brings us back to the factor of local conditions.

Chairman Hoak:—These two men have given a rather dim view of the possibilities of recovery of materials of substantial value from wastes. They have, however, made a couple of significant points. One is that companies faced with the necessity for giving their wastes reasonably complete treatment should not hold off in the expectation of finding a profitable by-product recovery process, but should rather install processes that will give them enough return to reduce the cost of treatment to a reasonable minimum.

Mr. Haseltine mentioned the steel industry specifically. It might be of interest to point out the amount of ferrous sulfate that could be recovered from pickling would be about 20 times

the current national consumption of that product.

Just as both speakers mentioned, recovery of waste by-products will frequently flood the markets for those compounds, whatever they may be. Thus, when a useful material is recovered by one organization or another, if several companies decided to do the same thing the price of the product would go down and no one would realize any profit.

Frank Woodbury Jones, Consulting Engineer, Cleveland, Ohio:—The problem of industrial wastes disposal is with us to stay. Some wastes must be treated at the source. This fact, although now generally recognized and accepted by industry, still needs considerable selling.

In selling the idea that wastes must be treated, it is but natural to suggest the possibility of return. However, in any case, industry must realize that a proper disposal of the process waters becomes part of the production cost.

Acid iron pickling liquor is a case in point. One concern is spending $60,000 annually for neutralization, and accepts the responsibility.

It cannot be emphasized too strongly that the best way to make money on by-products, is not to let them become by-products, but to save them before they become wastes. Good housekeeping can help.

In one recent experience, the loss of sulfuric acid was reduced 66 per cent by a critical study of operations. This is mentioned to show that there are great possibilities in preventing usable material from escaping.

Chairman Hoak:—That is a very good point. Anyone who examines the problem with any care will agree that the place to begin waste treatment is in the plant itself, by preventing the material from becoming a waste in the first place. I do not believe that most managements are aware of the potential savings that can be realized by conducting periodic surveys of all of their manufacturing processes.

Hayse H. Black, Senior Sanitary Engineer, U. S. Public Health Service, Cincinnati, Ohio:—I would like to make some comments that may tend to offset the dim picture that has been painted. Let us first consider oil losses from steel mills. The recent industrial waste pollution survey of the St. Clair-Detroit River section of the international boundary waters showed some 19,000 g.p.d. of oil being discharged, with roughly 80 per cent coming from one steel mill. Treatment of the waste from this mill would have meant treatment of about 170 m.g.d. to recover oil. This was economically prohibitive. The approach taken was to study and adopt ways of reclaiming and re-using oil.

In the case of Steffen waste from beet sugar manufacture, there is a very good chance that evaporation of the waste and incorporation with the beet pulp as cattle food will go a long way toward profitable by-product recovery.

It is true that some plants in a given industry will have an economic advantage over others. Consider recovery of phenol. One moderate size synthetic phenol plant can produce as much phenol as all the phenol that could be recovered from by-product coke wastes in the United States.

Re-use of white water in the paperboard industry also presents a good example of waste recovery. One mill showed a saving of $50,000 a year, from conservation of heat alone, by re-using process water. That is a return which we don't often consider.

William S. Wise, Chief Engineer, State Water Commission, Hartford, Conn.:—Being with a state agency that is trying to promote pollution abatement, I am gratified to hear the great emphasis being placed on puncturing of the balloon about getting wealthy in the treatment of industrial wastes. The pollution abatement problem has received a great setback for many years by the people who have been claiming all sorts of preposterous things in pollution abatement work and the treatment of industrial wastes.

Too much emphasis has been placed on the public health problem. There are thousands of industrial wastes discharged that have no effect upon the public health. Therefore, industrial waste treatment cannot be sold from that standpoint in many cases. Furthermore, no one needs to deceive himself into thinking that many industrialists are just poor suckers, because they know many of the problems. You cannot sell many of them on the idea that they are going to make a profit on the treatment of wastes, because they know ahead of time that it cannot be done.

Let's get down to earth. Let pollution abatement stand on its own feet and let's not try to think up and promote grandiose ideas, which cannot be substantiated, of what great benefits you are going to get out of pollution abatement.

Our water resources are limited; they must be conserved. Pollution abatement is one way to conserve them, because pollution is the greatest waster of water. When it comes to the recovery of by-products from wastes, I recall one small paper mill that for many years resisted efforts to put in a waste treatment plant. They finally installed the plant, and in two years the value of their product was sufficient to pay for the total installation of that plant.

The brass and copper industries in Connecticut are discharging thousands of tons of copper, brass, zinc, and chromium into the streams. Those brass companies knew there wasn't a great profit in the treatment or in the recovery of those thousands of tons, because it costs them more money to recover than the products were worth.

Research has gone forward on brass mill waste treatment. Still, at the present time, no one is promising a profit. However, the recovery of those products can be made at a cost which will reduce their treatment plant problem to a very small figure compared to what it would be if they had to treat it without recovering anything.

I am thinking of one plant whose operating costs might be $80,000 a year, whereas to recover the products that can be used right back in the mill would be worth about $60,000 a year. The large majority of industrial concerns seem to feel that it is necessary to make some monetary contribution to clean streams, and many of them are perfectly willing to pay something for cleaning up the streams over and above the value of their products.

The attitude that recovery should be abandoned or never instituted because it doesn't produce any profit is short sighted. There may not be a profit, but there is some value and in many cases it very greatly reduces the cost of the treatment of waste.

J. R. Hoffert, Chief Engineer, Pennsylvania Department of Health, Harrisburg, Pa.:—I would like to endorse some of the statements that have been made.

My own feeling is that every case should stand on its own merits. We should look at industrial waste treatment realistically. First of all, we may as well realize that we will have to treat industrial wastes whether we like it or not. The public has decreed that.

Secondly, we should consider what properly comes under the heading of industrial wastes. It is surprising how many industries send down the sewer things that they do not even realize are going there; things which should not be in the wastes. Mr. Jones spoke of that previously. We have had plenty of instances in which a little good housekeeping—something you'd think a good businessman would practice—would have greatly reduced the amount and concentration of the wastes. After you have applied waste reducing and segregation and have come down to a reasonable volume and strength of raw waste, then is the time to consider treatment. Treatment under proper cost accounting may not look as impractical as sometimes pictured. The

first step is to determine what offsets there are to its "cost" through reducing the volume of wastes which must be disposed of or through recovering useful by-products, which perhaps will not yield a "profit" but will tend to offset the direct cost of disposal.

I have said time and time again that when we spend as much effort on finding the best means of handling wastes, by changes in processes or by other means, as we do in studying technological improvement of our products, we will surprise ourselves by the number of instances in which wastes are turned into profitable by-products or there is a "break-even," or a reduction in the cost of treatment.

I would like to emphasize the fact that "selling," as Mr. Jones said, is very important in dealing with industrial wastes as well as with the finished products. A few years ago, ice cream was a luxury; today it is an essential food product and its consumption has increased correspondingly. The change has been largely due to good selling campaigns.

So, too, with wastes. Calcium chloride was at one time a waste product, yet it is now being used to advantage in many places. You could go on with many instances in which by a little thought or some research, and good salesmanship, a market for a "waste" has been created which did not exist before. In some cases the waste has become the main product. Today the one-time wastes of the meat packing industry are responsible for a large part of its profits.

Such steps as the foregoing tend to offset the cost of waste treatment. I do not think we need have quite as dim a picture as has been painted if we consider the situation on its merits by true cost accounting methods.

Treatment of Industrial Wastes with Domestic Sewage

Chairman Hoak:—There is a great deal of interest, and there should be, in the possibility, wherever it may exist, of treating industrial wastes along with domestic sewage. The timeliness of this particular topic is the reason for including it in this forum.

Samuel I. Zack, Chief Sanitary Engineer, Gannett Fleming Corddry and Carpenter, Harrisburg, Pa.:—Treatment processes suitable for domestic sewage are adaptable for treatment of organic types of industrial wastes if treatment plant units are properly designed and sized for the additional pollution load of the industrial wastes.

A trickling filter plant designed for a domestic population of 6,000 persons and a flow of 0.6 m.g.d. at North East, Pa., continued to function, but with greatly reduced B.O.D. removal efficiency, when handling design flows including industrial wastes with a population equivalent, due mostly to colloidal and dissolved organic matter, amounting to more than six times the domestic sewage load during the 1949 season of processing cherries, tomatoes, and grapes. In this case, the seeding effect of the sewage is undoubtedly of material benefit in the biologic treatment of such wastes, but additional trickling filter capacity or biologic treatment units of another type are needed to improve treatment efficiency.

Industrial wastes having a high content of organic solids in suspension can be treated with sewage by primary, chemical, or biological secondary sewage treatment plants when sludge handling and disposal units (such as pumps, sludge digesters, drying beds or vacuum filters for dewatering, dryers for heat drying, and incinerators for burning sludges) are properly sized for the additional sludge removed.

Pretreatment of the industrial wastes at the source or at the sewage treatment plant can provide a means for reducing the organic load to be within capacity of available treatment units. Pretreatment by screening through perforated plate or wire mesh fine screens to remove screenable material is a necessity if fruit and vegetable canning or processing, packinghouse, tan-

nery, or various textile wastes, etc., are to be treated with sewage at a sewage treatment plant.

Industrial wastes with material amounts of organic solids in solution or in suspension which contain acids, alkalies, toxins, grit, clay, glass, and abrasive particles from pickling, plating, cyanide, tanning, and canning processes or from the production of coal, glass, and ceramic products are detrimental to biological processes for treatment of sewage and digestion of sewage sludge or unnecessarily complicate sewage treatment and sludge disposal. Although such wastes can be presettled, neutralized, or otherwise pretreated at the source or at the sewage treatment plant to be nondetrimental for treatment with sewage, the preparatory treatment required usually makes them suitable for discharge to the receiving stream without appreciable further treatment. Therefore, separate treatment of inorganic industrial wastes is more economical and practical than treatment with sewage and considered to be less troublesome. However, when the proportion of these wastes is small compared to the total volume of sewage, they can be absorbed for combined treatment without detriment.

Large quantities of relatively uncontaminated cooling waters have no harmful effect on sewage treatment plants except to use up capacity and dilute the sewage, and should, as a matter of economy, discharge direct or through storm drains to receiving waters or be reduced in quantity by use of recirculating systems or cooling towers.

It is preferable to take out much of the organic oils and greases from industrial wastes by preparatory treatment before treatment with sewage. After removal of inorganic oils and greases from waste waters not otherwise contaminated, no further treatment is required for final disposal.

Cannery, textile, and dye wastes can be treated with sewage except that it is often found desirable and economical to reduce the color and organic load by chemical precipitation and sedimentation type of pretreatment ahead of biological type of secondary treatment. In such cases, the sewage is beneficial as a seed to aid biological action.

Periodic discharge of industrial wastes at high rates, or temporary discharges containing excessive amounts of acids, alkalies, or toxins, can upset the normal functioning of a sewage treatment plant. These difficulties can be minimized or overcome by equalization tanks at the source designed with controls to provide relatively uniform discharge.

The character, quantity, and rate of discharge of a particular industrial waste has a definite bearing on its treatment with sewage and its effect on the individual treatment units, as well as in the general treatment process. These factors must be evaluated as the basis for design, correction of treatment plant operating difficulties, determination of the course of pretreatment of industrial wastes, or their exclusion from the sewers.

In this brief introduction it has been possible only to touch on the high spots of a very broad and varied subject, but it is hoped that a nucleus has been provided for further development and discussion of more specific data, information, and policies pertaining to this important problem.

T. C. Schaetzle, Sr. Associate Engr.-in-Charge of Sewage Treatment, Akron, Ohio: *—The treatment of industrial wastes with domestic sewage is such a broad subject that it could consume considerably more time than is allotted for this discussion. There are four general topics worthy of consideration:

1. Should industrial wastes be accepted for treatment with municipal sewages?

2. What charges should be made for such treatment?

* Read by Chairman Hoak.

3. If accepted, what pretreatment is necessary?

4. What effect do such wastes have upon municipal sewage treatment processes?

In this discussion, the first two and last two topics will receive joint consideration.

The acceptance of an industrial waste into a municipal system depends on the type and volume of the waste in relation to the size and kind of sewage treatment works provided by the municipality. In general, the trend is toward acceptance of such wastes when they can be handled without material detriment to the proper functioning of the treatment works or to the receiving body of water, but not necessarily without some pretreatment. It is my opinion that some penalty charge should be made, based on any or all of the following: pH value, suspended solids, and B.O.D.

Personal experience indicates that shock loads are detrimental to the various treatment processes in the following order:

1. Activated sludge.
2. Chemical precipitation.
3. Trickling filters.
4. Plain sedimentation.

Shock loads may upset the equilibrium of a sewage treatment works by a decided change in the alkalinity or acidity of the raw sewage. Such a change may reach the isoelectric point at which the dissolved solids are converted to suspended, thus materially increasing the sludge load and increasing the solids content discharged from the settling devices and, in turn, overloading the secondary treatment process. This is exactly what happens at Akron when the normal pH of the raw sewage increases from about 7.0 to approximately 8.3. Under these conditions the incoming raw sewage is flocculated and has the golden brown appearance of good activated sludge.

With frequent changes in reaction throughout any given 24-hr. period, the activated sludge process can be thrown completely out of equilibrium, and in chemical treatment the correct proportioning of chemicals is increasingly difficult, especially at small plants where proportioning devices are not installed. However, if the sewage does not become acid, little, if any, difficulty is encountered with trickling filters.

In attempting to overcome shock loadings, care must be exercised so as not to demand too much of industry. We should remember that they must show a profit if they are to continue to function. Thus, cooperation rather than enforcement of ordinances is of paramount importance if the efforts of the municipality are to bear fruit.

Two of the simplest and least expensive methods in use are holding and reaction tanks, the former to permit a gradual discharge of the industrial waste over a long period rather than in large quantities over a brief interval, and the latter for an adjustment of the industrial waste to a pH value approaching that of the municipal sewage.

A second type of industrial discharge, which is not as easily handled, is one in which the solids load to the treatment works is increased beyond the plant's capacity and is of a continuous rather than an intermittent nature. Such has been the case at Akron for years. During the war period, the suspended solids jumped to 80 tons of dry solids daily, or more than three times the designed capacity. No solution other than pretreatment by industry is applicable to this situation. Fortunately, such pretreatment resulted in a return to the rubber-reclaiming plants.

Wherever and whenever possible, sewage treatment employees should do what they can to help develop a profitable pretreatment process.

Such wastes as copper, cyanide, and the like, may upset the sludge digestion process to such an extent that their exclusion from the municipal sys-

tem seems to be the only positive solution known at present.

Finally, floating wastes, such as hair, feathers, entrails, etc., from various slaughtering establishments should and can be removed by proper screening at their origin. Grease presents another problem, which can be minimized at its source by aeration, aeration and chlorination, or aeration followed by quiescence and skimming.

The small municipal treatment works oftentimes have more difficulty with industrial wastes than the large ones. In such cases, it may be that one sizable industry discharges wastes equivalent to that of the entire municipality. I have in mind one plant which I supervised. A manufacturer canning pickles, mustard, relishes, jams, etc., could not be induced to install a screening and settling unit and the village officials were fearful of driving the industry out of town if forced by ordinance to do that which would be beneficial to the treatment works. As a result, the two operators had to put up with poor settling efficiencies and frequent plugging of the trickling filter nozzles.

In another instance, a pretreated waste from a slaughtering establishment was added to the village sewage without reducing the plant's efficiency, but an odor problem developed. Although not entirely unpredicted, nevertheless, this may mean an added expense for the village.

I believe these incidents indicate that municipal officials, as well as industry, need further education so they may know that sewage treatment works are not foolproof and do need some protection against being made a "catch-all."

Chairman Hoak:—This topic is a very timely one because more and more industries are considering, along with the municipalities in which they are located, the feasibility of handling their waste with the municipal sewage, with or without pretreatment.

Clair N. Sawyer, Mass. Inst. of Tech., Cambridge, Mass.:—There are two other points that should be brought out. Nitrogen is also a factor frequently causing trouble when industrial waste high in protein content is discharged to a municipal treatment plant. The normal basis of evaluating the treatment of such wastes is on suspended solids and B.O.D. However, nitrogen increases the load on a plant appreciably in addition to what would be expected from B.O.D. The plant at Sioux Falls, S. Dak., entered into a new contract by which the industry keeps nitrogen losses at a certain level and pays a charge for anything over that.

The other factor which ought to be kept in mind is the matter of location of industries and the difficulties that sometimes occur due to misunderstandings by municipal officials. Quite often the local Chamber of Commerce is at fault rather than the officials. The Chamber of Commerce usually does a good selling job, without any regard as to how well the community is able to take care of any particular industry and its water problems.

Mr. Haseltine:—There are a couple of points I would like to emphasize.

Mr. Zack stated that organic industrial wastes could be treated with sewage if the sewage plant was large enough. At present there are a lot of communities that have had no sewage treatment but are now in the process of working up designs for their plants. The engineers should be and are capable of designing a plant that will handle the municipal sewage alone for so many dollars, or they can figure out a larger plant that will handle the municipal sewage plus the industrial waste for so much more.

Obviously, the difference between those costs is the cost of handling the industrial waste. Where that cost is distributed over a large number of industries, it is one thing. Where it is all chargeable to one particular industry, that is another problem. We had this problem a while back. The

industry was a large one and the community would have sustained a real loss in losing it. Nevertheless, to build a sewage plant to handle the industry's waste would have cost 50 per cent more than to have built one excluding it. We could give the municipality the costs either way, but did not consider it proper to make any recommendation. When the industry heard of those costs, they said: "Nuts! We will close up shop and move out rather than pay that difference."

In a way they were right. There are intangible benefits from having that industry there that nobody could put a dollar-and-cents value on, or it would take a very complex survey to arrive at any figure, and then it would be open to question. In this particular instance the community and the industry met together and arrived at a figure by discussion and arbitration, which seemed to be reasonable to them both.

The city is paying much more for its sewage treatment than if the industry had been excluded, but they are keeping the industry there.

Chairman Hoak:—There is one point brought out in Mr. Schaetzle's paper that may not have been emphasized quite enough. Industries do not always seem to understand why it is necessary to make supplemental charges for treating their waste along with sewage. Mr. Schaetzle mentioned that, in some instances, the population equivalents of the wastes from the industrial plants have been equal to those of the communities. I know of a number of cases where the equivalent exceeded the population of the community. When an industry imposes a disproportionate burden on the sewage treatment works as a result of its discharge of waste, a charge must be collected from it. In many cases, that charge will be smaller than if the company had to install its own treatment works.

George B. Mebus, Consulting Engineer, Glenside, Pa.:—The matter of accepting organic wastes for treatment with sewage is not as simple as it sounds. That is true for several reasons. Frequently, instead of having solids that can be removed from the bottom of the tank, they are all found on the top. Generally, the carbon-nitrogen ratio gets so far out of balance that the normal biological process does not function the way it should.

As regards cost, there are cases where the cost of enlarging a municipal plant to accommodate industrial waste is more than the cost to the industry if the industry were to construct a plant to handle its wastes alone. That isn't always possible in some instances because of space adjacent to the industry, and that is a matter that requires separate consideration.

Don't be misled. Because wastes are solely organic in character, it does not necessarily follow that they can be handled as a routine matter in the operation of any municipal sewage treatment plant. It isn't quite that easy.

Chairman Hoak:—That is a good point. We know there are a lot of wastes that cannot be treated practically with domestic sewage, but, wherever it is possible, there are instances in which the cost is lower for all concerned.

C. C. Ruchhoft, Sanitary Engineering Director, U.S.P.H.S., Cincinnati, Ohio:—It has been my privilege to have had some contact with a number of installations in the atomic energy industry and it occurred to me there may be some interest among the members as to the disposal problems that occur. Of course, this is an industry in which it has become apparent that it is not desirable to make a mixture of the industrial wastes with domestic sewage. As far as I know, the installations have maintained separate systems for the collection of industrial waste and domestic sewage.

The Atomic Energy Commission has established a definite policy of retaining control of all radioactive wastes and treating them, rather than simply discharging them for dilution. An entirely new profession—that of health

physicists—has been developed. The health physicists are very much aware of the new problems with which they are dealing and are taking every precaution to see that no untoward results occur from discharge of radioactive wastes.

These problems are being studied. All the solutions have not been obtained. I am sure there will be no discharge of any dangerous wastes from any of the A.E.C. installations. Some may question the discharge of certain isotopes from hospitals and other industrial users. This problem is being studied also by a committee of the National Bureau of Standards, and there will be a report as to the disposal of isotopes from hospitals in the very near future. This does not seem to be a very large problem, and it should be solved by simple precautions in the hospitals.

Mr. Zack:—Since the matter of costs has been brought up, I would like to comment on that. The conception of what a municipality can afford and what it cannot afford is wrong. To talk about a plant costing $1,500,000 is one thing in the taxpayer's mind; but to talk about a plant whose construction and operation can be financed for the cost of the daily newspaper is quite another. People throw away for odds and ends many, many times the money that it is going to cost a family to build and operate a plant.

I make that comment in view of Mr. Haseltine's viewpoint that probably, if it is reduced to its elements, the people who have to pay the bill can be sold on the idea that it did not mean much in the way of dollars per year to take care of an industry's wastes and to keep it in town.

On the other hand, there is the attitude of the industry itself. Talk about a $300,000 plant and the reaction is that they cannot afford it. Reduction of the cost to what it is per unit of material produced in the plant lessens opposition considerably.

Mr. Wise:—There is another point that hasn't been emphasized sufficiently—industry's obligation when they are privileged to discharge their waste into the municipal sewer system. I have frequently discussed this subject and advocate it in those cases where too great a burden is not placed on a municipality through operation and maintenance problems.

They, of course, do not always work out satisfactorily. I advocated the discharge of some wastes in the municipal sewage system in a certain municipality following pretreatment. There is no doubt but what those wastes have no detrimental effect on the operation of the treatment plant when the pretreatment processes are properly operated and maintained. This particular industry was lax for a year or two in operating the pretreatment process. Every so often it was broken down, due to lack of proper maintenance, and the treatment plant was put out of operation for extended periods.

In another Connecticut city we are advocating the discharge of some industrial wastes into the sewer system. Also, we are advising that very definite agreements be drawn between the municipality and the industries contributing the wastes for proper inspection and maintenance of the pretreatment facilities in every case where pretreatment will be necessary.

In nearly every case, it is to the industry's advantage to discharge its wastes into the sewer system if the system is designed to accommodate them. On the other hand, it is to the city's advantage to keep the industry there and operating well. Therefore, there is a mutual advantage. However, the industries have to make up their minds to operate the pretreatment facilities just as carefully and as well as they operate their own production and processing operations. In many cases, when that happens, the combined treatment can be carried on to the mutual benefit of the municipality and the industry.

Chairman Hoak:—The threats of industry to move out are not too serious because industry, by and large, is not very mobile.

Linn H. Enslow, Editor, Water and Sewage Works, New York, N. Y.:—Mr. Schaetzle should add one more factor in estimating the cost of treatment of industrial wastes with domestic sewage. He did not mention chlorine demand, which should be inserted in the list. He has already agreed that the omission was an oversight.

I should like to go one step farther and advocate something more than "good housekeeping"—that is, "better housekeeping." I mean going back not only to curtail losses, slop-overs, and things of that sort, but also a reconditioning of processes or revising the processes, wherever possible, in order to reduce or even eliminate certain types of wastes. That already has been done by some large industries in this country, in some instances to marked advantage.

Pulp and Paper Mill Wastes

Harry W. Gehm, Technical Advisor, National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries), New York, N. Y.:—The statement sometimes made that research is employed by industry to delay industrial waste treatment is certainly open to examination. There is no question but what research has occasionally been so used, but it is not a purpose subscribed to by thinking minds of industry. Real problems, some virtually staggering, exist; industrial waste treatment is by no means as simple, technically or otherwise, as municipal sewage treatment. Actually, it is a cost and practicability problem. Most industrial wastes can be treated. However, in many cases costs are prohibitory or the available methods, if applied, would give rise to other problems often of greater public concern than stream pollution. The goal of research in this field is, and will remain despite what any individuals or groups may wish, the finding of economical and workable methods for reducing industrial pollution.

In the pulp, paper, and paperboard industries, which have been long active in research and which still face serious pollution problems, progress in actual waste treatment has been far from discouraging when the facts are examined. The writer has personally inspected waste treatment and control works either in operation or under construction at over 100 mills in this country. It is true that all these do not provide a degree of treatment as high as may be desirable, but it does represent an effort of a magnitude which cannot be ignored. Coupling this figure with the number of mills whose waste does not require treatment due to the availability of great receiving water dilution, those which have achieved control through the application of modern high-efficiency recovery equipment, and making a minimum allowance for those concerning whom information is lacking, it is evident that well over 50 per cent of the industry either have the problem in hand or are taking concrete steps to do so. When it is considered that most of the progress has been accomplished during a ten-year period, during which the industry expanded production more than 1,000 per cent, radical changes in manufacturing techniques occurred, and, during the war period, construction materials for waste treatment were not readily available, progress has been remarkable.

Remaining problems, for which solutions have been very slow in coming, tend to overshadow in the public mind the progress already made. Let us review several of these briefly in an effort to analyze them in respect to the approaches made to solve them and determine the reason why more rapid progress has not been forthcoming.

In cooking for sulfite wood pulp, about 50 per cent or more of the wood is cooked out in the form of cementing materials and sugars. The wastes consist substantially of about a 10 per

cent solution of dissolved organic matter. About 7 per cent of this is calcium sulfate, about 2 per cent wood sugars (namely, dextrose), and the remaining 1 per cent is hemicellulose and similar materials.

The effect of sulfite liquor on streams is mainly as follows:

1. It is a great oxygen depleter, because the population equivalent per ton of pulp is in the neighborhood of 3,000 to 4,000.

2. It is brown in color, rather highly colored. This is not objectionable from the appearance standpoint, but it is difficult to remove by downstream water treatment plants. Another difficulty is the formation of slimes. They are important from the standpoint of fish nets. Commercial fishermen complain that the slime on the nets lowers net life and requires more frequent cleaning.

The approach for a great many years has been the possibilities of recovering by-products from this vast amount of material. The previous discussers have adequately pictured the situation with respect to by-products recovery. After years of research in Europe and in this country, it is found possible to unload only about 5 per cent of the sulfite liquor in the form of by-products in this country at present. In fact, practically every mill that does make by-products from sulfite liquor wish they had never seen them. This applies particularly to the sales department, which generally finds itself in an unenviable position with respect to competition.

At present, a small amount of liquor is evaporated to a 60 per cent consistency. This material can be used for core binders and general adhesive purposes.

A short while back, a mill added its production to this market and cut the price right in half, which was a very apt demonstration of how good that market was.

So we cannot expect much there in the future for reducing sulfite liquor discharge. There have been fermentation products made. Some ethyl alcohol is made in this country under peculiar conditions. Either unusual marketing conditions prevail or the plant was bought at a low price from the government. The question of the operation of such a process continuously is rather doubtful technically when the petroleum industry can make ethyl alcohol for a third of the price.

At present, there is experimentation with respect to the production of fodder yeast. There is one full-scale experimental setup operating in Wisconsin. However, here again considerable economic and operational problems are involved and fermentation by-products frequently are not capable of doing very much in the way of improvement of wastes from the pollution standpoint.

There are very few available markets for a large bulk of this material. Even if we could produce the product, and at the right price, we could not possibly absorb it. The industry is pretty much resigned to the fact that no gold mine will be found in sulfite waste liquor.

The next major approach was in the treatment of this waste. There were various means of oxidation applied, both aerobic and anaerobic. Experimental work showed that considerable reductions in oxygen demand could be achieved, and at much higher rates than are ordinarily observed for sewage treatment. However, when the population equivalent figure of 3,000 to 5,000 per ton is considered, the treatment plant required would dwarf the parent mill. So, as an over-all solution, treatment of the whole liquor as such has been put aside.

The point has been made by previous discussers that the best use of any material can be made right within the organization producing it. This was the next direction of sulfite liquor research, which looked toward recovery of the chemicals from the liquor. A calcium-base liquor is extremely difficult from the recovery standpoint, because it is

difficult to handle. The heat input for evaporation is very high in relation to the heat available for burning the concentrated liquor. The extremely high rate of calcium sulfite scale deposition makes evaporation an even more inefficient process. A third difficulty is that of fly ash. The calcium-base liquors, when burned, even with precipitators, give the surroundings the appearance of a cement mill unless the burning is under rigid control, as the ash content of the liquor is three times that of coal.

The possibility of changing the base of the cooking liquor has been investigated. Calcium-base liquor is thin, due to the fact that calcium bisulfite is fairly insoluble in water. There is the possibility of changing to a base such as ammonia, with which they could cook to a higher consistency and get a thicker liquor. That would require less heat for evaporation and have the advantage of being relatively nonscaling.

Another possibility was magnesium oxide or magnesium sulfide. One company, in conjunction with an equipment corporation, has financed the work on magnesia as a base. The pilot-plant work looked encouraging enough, so it was decided to go ahead on a full-scale basis. This necessitated completely rebuilding the mill, even to the extent of building a new mill. Only the digesters were salvaged from the old job. The plant was built at a cost exceeding $20,000,000 and has now been in operation almost a year. To make this process successful, high recoveries of magnesium oxide and sulfur dioxide are necessary. Ordinary limestone used in a calcium-base product runs about $5 a ton, whereas the magnesium runs about $60 a ton. The results to date have not been encouraging. Recoveries haven't reached expectations and numerous operating and equipment problems have developed.

Difficulties have arisen within the process, such as corrosion, scaling, and interference of foreign materials reaching the process (for example, sodium chloride). Enough salt can get into the process from logs which have floated in salt water to give trouble. When the salt concentration builds up in the recovery system, it forms a compound with the magnesium and that scales out during the burning.

As a result, the future of the magnesium process is in considerable doubt. At present, the company supplying the equipment will not quote on another job until more success is shown than has been indicated to date. However, this work represents a tremendous effort in the right direction.

The second process investigated is the ammonia process. This is similar in principle to the magnesia process, except that the ammonia cannot be recovered to any economical degree and ammonia is considerably more expensive than calcium carbonate. It does offer the advantage of less plant change than magnesia, as a sulfite mill can be converted without being rebuilt completely. There are three mills operating experimentally on ammonia as a base.

The problem in this case is in the burning. The mill that has operated the longest and done the most work still has considerable trouble with carbon forming in the liquor during the evaporation process. The other difficulty is the problem of making the necessary grades of pulp. Sulfite pulp is not one product, but several products produced by different degrees of cooking and having different characteristics, depending on the use of the pulp. Therefore, it is necessary with the new process, such as ammonia, to be able to duplicate those pulps. A lot of work has been done in the direction of producing the grades necessary as a result of the ammonia process.

There have been two sodium-base operations that have operated intermittently. The difficulty herein lies in recovery of sulfite on the burning of the soda base liquor. This would have to be oxidized to be used in the process. Where a kraft mill and a sulfite

mill are close together, the kraft mill can take the sodium sulfide produced by burning the sulfite liquor and the rest of the alkali is formed as make-up in the process. However, the amount it can take is very small, and a very large kraft mill would be needed to handle the liquor from a very small sulfite mill.

There is one difficulty with any recovery process—the limitation of size. If any recovery plants are built, the minimum size of the mill would have to be in the neighborhood of 200 tons per day. Unfortunately, there are many small sulfite mills in the range of 50 to 100 tons, and recovery is not likely to fit their specifications. In an effort to handle their problems, particularly when they are seasonal, work is now being done on seasonal lagooning. Lagoons in the sulfite industry have a bad name. Most of them that have been built have leaked because the soil or clay liner has shrunk. Experimental work is being done with asphaltic-type liners and different types of sealing materials to see if a lagoon can be built that will remain tight.

Another direction in research for a small mill is the work at Oregon State College on heat hydrolysis. In this process the liquor is heated to 400° F. under pressure. Such treatment, under the acid conditions of the liquor, hydrolizes the sugar to carbon dioxide and water, and precipitates a portion of the lignin. It has been possible to get oxygen demand reductions as high as 90 per cent in the laboratory. This work is now going into the pilot-plant stage, and we have hopes that it will be both workable and economical for consideration by smaller mills.

Some work is also being done with the type of materials that stimulate oxidation of the waste directly. The status of that work is such that one day it looks promising and the next day it does not. It is one of those things so little understood that we are really in the exploratory stage.

Despite the fact that research and development does not move fast on these problems, actually, there is no other course for industry or anyone else to take toward their immediate solution other than the suicidal process of putting ourselves out of business.

B.O.D. of Industrial Wastes

Chairman Hoak:—No more controversial subject could be put on the program than the applicability of the B.O.D. tests to industrial wastes. There has been a good deal of conversation during this meeting about the B.O.D. determination, and I hope that many of the questions can be answered in this discussion.

R. S. Ingols, Georgia Inst. of Tech., Atlanta, Ga.:—The biochemical oxygen demand (B.O.D.) test for the analysis of industrial wastes is very important, if not essential, for the measurement of the strength of those wastes containing organic matter. On the other hand, the B.O.D. value received from the single analysis of any specific industrial waste is completely worthless unless the analyst is qualified to interpret the value in the light of all of the information that is or can be made available about that waste. To obtain only a B.O.D. value on a strange sample of industrial waste is wholly insufficient, but the B.O.D. value must be used along with results of other tests as an index of the manner in which the waste may affect the receiving body of water.

Of course, because the test is biological, it must be assumed that the analyst is sufficiently acquainted with biology to know the weak spots and pitfalls that must be overcome in setting up the test on an industrial waste. That some of us who have spent several years in intensive research on the test do not find it easy to overcome all of the pitfalls at the first try is most unfortunate. In the past, some research workers in the field have discussed their studies of the B.O.D. test, but the results of their studies on the degree of variation that can be expected on a statistical basis with the B.O.D. test have not been

published. Perhaps this policy has been changed, for recently three articles appeared showing some weaknesses of the test. The first, by Ruchhoft, showed the interference of the nitrification phase. The second, by Sawyer, showed that some domestic sewages do not provide an adequate seed for the analysis of simple materials when the test is used with the usual 5-day incubation period. The third, by the speaker, showed the variability of the 5-day B.O.D. values of the same sample of sewage after that sample had been stored for several hours prior to the usual B.O.D. analytical procedure.

The unwillingness of many to face the truth concerning the weaknesses of the B.O.D. test has brought its obvious reaction from those who have tried to use the test by following the standard methods, and is in part responsible for the round-table discussion we are having. However, the many weaknesses of the test are now known sufficiently to convince many practical chemists and engineers that the test should be discarded in favor of the best test for the determination of the total organic matter in the waste, possibly, the dichromate oxygen consumed procedure of Moore, Kroner, and Ruchhoft. In this I do not concur, although the truth about the test should be known and realized.

Why is the B.O.D. test so difficult to perform? Principally, it is difficult because the test uses bacteria and possibly other organisms, which must live and grow in the test bottle to use up the oxygen. What does this mean? To an analytical chemist, a good technique may yield an accuracy and reproducibility of one part in 1,000 and may be acceptable if it yields an accuracy of one part in 100. To a biologist, the results of an analysis of biological material is considered excellent with an accuracy and reproducibility of one part in 100, and must be acceptable with an accuracy and reproducibility of one part in 10.

The analysis of a biological material by physical or chemical test can frequently be carried out with a reproducibility of one part in 100, whereas the measurement may be one part in 10 or less from the true or average value for that particular biological character.

Thus, the height of an individual man can be measured very accurately, but it does not mean that it represents the true or average height of the adult male of the species.

Good reproducibility, but poor accuracy, is frequently true of the analysis of a simple sample by the B.O.D. test, even under the best conditions. Two good examples of this characteristic behavior of the variability of the values obtained from samples analyzed by the B.O.D. test were published independently in January of this year, as mentioned earlier.

However, industrial wastes frequently do not provide the best conditions for either reproducibility or accuracy in the B.O.D. test. Thus, the B.O.D. test must be approached with the realization that it cannot be expected to perform with the accuracy of a chemical test, but that it can yield a valuable index of the amount of work that the organisms of the stream may be able to perform in reducing the D.O. of the stream. A large number of tests must be made in determining the B.O.D. value of an industrial waste with a willingness to find and eliminate all of the possible interfering factors and then to study the degree of variations of the values about the norm.

The two techniques that offer promise in the determination of the true B.O.D. value are:

1. The use of more than one B.O.D. value for the calculation of a good result, as discussed by Moore.

2. The use of a manometric technique instead of, or as well as, the usual dilution method, as recommended by Heukelekian and his colleagues.

Raymond W. Hess, Head, Pollution Research, National Aniline Div., Allied Chemical and Dye Corp., Buffalo, N. Y.:—As I see it, the three major problems requiring thorough attention if B.O.D. for industrial wastes is to have sensible application and practical use are:

1. The proper relationship of conditions for B.O.D. determination of effluent to conditions for oxygen depletion of receiving waters.
2. The relationship of oxygen depletion of receiving waters to its proper use in each location in this densely populated, highly industrialized age.
3. A reliable analytical method for B.O.D.

Assuming that we have a reliable analytical method for B.O.D., there is still a very complex problem in relating it to what effect it will have on receiving waters. How can the conditions in the B.O.D. bottle be related to the concentration, temperature, time, chemistry, and biology, which vary widely in receiving waters? Furthermore, a researcher knows how greatly different are the results for a constant under different combinations of variables. For example, there is no reason to expect the same degree of oxygen depletion, even if the concentration, temperature, and time are held constant while the chemical or biological components are varied.

This line of thought suggests that, instead of arbitrarily determining the B.O.D. at certain concentrations for five days at 20° C., more attention should be given to duplicating in the B.O.D. bottle the concentration, temperature, time, chemical, and biological conditions of receiving waters for each particular waste.

Assuming that we have a reliable analytical method and can properly relate the B.O.D. to oxygen depletion in receiving waters, it is highly important to relate the significance of oxygen depletion to proper uses of receiving waters. A proper use for some waters is fish survival. Such waters should be allowed to have less oxygen than waters to be used generally for fishing; for the latter, greater depletion of oxygen should be allowed than for trout streams. Completely depleted water for industrial cooling is less corrosive, unless the presence of sewage or certain other wastes results in production of hydrogen sulfide or other corrosive substances, and should be permitted unless there are either other proper uses or serious nuisance conditions involved.

A recent publication states: "The effect of sewage or industrial wastes in depleting the dissolved oxygen content of the receiving water is generally accepted as the most direct index of the strength of the sewage." Assuming that this is generally true, there still remains the problem of how to obtain this index from the B.O.D. bottle by relating the analysis to the receiving water. Assuming that such an index can be obtained, there is danger of applying it too broadly. It is possible that attention should be directed to other characteristics, such as toxicity.

The solution of the problem of properly relating B.O.D. to use of receiving waters is to be found largely in the exercise of good judgment.

It is no secret that even the same analyst can't get the same B.O.D. for a given waste at different times because of variations in seeding material, as Dr. Ingols has shown. Furthermore, the results for different wastes would be befogged, even if standard seeding material should be available, because of variations in the kind and amounts of nutrients present. In the analysis itself, independent of its relationship to receiving waters, there is no problem of temperature, time, and concentration as some seem to think. The results can be readily duplicated under the same conditions, but the question is: What do they mean for practical use? However, they will be more meaningful if the number of dilutions

is sufficient to level off the B.O.D. concentration curve.

Varying results due to the varying nature of seeding material call for elimination of this variable. Possibly, this can be done by use of a pure oxidizable material, with the seed used for the sample, as a control for each B.O.D. determination. We are doing some experimental work along this line. It is understood that others are working on this by use of pure cultures and also on standardizing the nutrient problem.

The shortcomings of the B.O.D. analysis can be offset to a considerable extent by making the number of B.O.D. analyses indicated to be necessary by statistical analysis, but this presents another problem in the nature of the large amount of time and work required.

This statement may seem to be very critical, but it also makes some suggestion which it is hoped will be regarded as constructive and stimulative to further constructive thought, discussion, and action. As I see it, to some extent, we are improperly using a tool which is poorly adapted to the purpose but which has possibilities for marked improvements in both respects.

Professor Sawyer:—First, I would like to make the statement that I have no quarrel between B.O.D. and the so-called oxygen demand tests or chemical oxygen demand tests, as they are proposed today. We use both in our laboratory and both of them have been helpful.

Of late, the B.O.D. test has been kicked around quite a little. We have been working on it in our laboratories for the past three years trying to improve its reliability and I think we have come up with at least one or two things which perhaps were not fully appreciated in the past.

In almost all analytical work involving use of volumetric methods the analyst is careful to use primary standards or certain well chosen secondary standards for evaluating the potency of his critical reagents. Now let's look at what we have been doing in B.O.D. work through the years. We have been taking some distilled water, putting in a few mineral salts, seeding the bottle from a grab sample of sewage, running B.O.D. tests, and reporting the results!

Well, it doesn't seem to add up as far as I am concerned. So, one angle of our attack has been to try to develop a scheme for standardizing our B.O.D. dilution waters. Through the course of the years, we have found that many of the old stills used around the country are throwing copper, and copper is not very good for the development of bacteria. Consequently, we get an inhibition during the test and a result which may be 50 or 60 per cent of what would have been obtained if the copper had not been there. The results are, nevertheless, reported as such. We do not know any differently, so to speak.

An effort has been made to develop some primary standards and two have been proposed in an article published in SEWAGE AND INDUSTRIAL WASTES (Jan., 1950, p. 26). They are helpful in the work now being done. It is not outside the realm of possibility for each individual laboratory to have a so-called "reference" solution, which can be used to standardize the B.O.D. work. It might be an industrial waste, of a stable nature at high or low pH.

So it is reasonable that each one who has industrial wastes problems should have a standard reference industrial waste solution on the shelf to use every time a B.O.D. test is to be run. If the results are out of line, they can be thrown out and a redetermination made. But at least you know whether they are reliable results or not.

Chloramines will affect B.O.D. determinations. Most stills have no provision for removing the chloramines by activated carbon. Therefore, they are carried over into the distilled water, and will cause low B.O.D. results.

A second matter is that of seeding. In the past we have always seemed to

accept the use of sewage as giving a satisfactory seed. Using the proposed primary standards (glucose and glutamic acid), as well as three industrial wastes, we have found sewages from various sources to vary tremendously in their potency. With sewages from 30 locations in Massachusetts used as seeding materials, the 5-day B.O.D. values on 300-p.p.m. solutions of the primary standards varied from 134 to 240 p.p.m. on the glucose and from 122 to 222 p.p.m. on the glutamic acid. Using an industrial waste (cotton kiering liquor) as a reference solution, the B.O.D. obtained ranged from 9,300 to 13,900 p.p.m.

When the same samples were analyzed with sewage seed from the Ward St. pumping station in Boston, representing a large collection system, the range of 5-day B.O.D. results was much narrower (Table I). From these data it can be seen that the B.O.D. test can be expected to give results of reasonable precision for a bio-assay method when a uniform and dependable seeding material is used. Further studies in our laboratory have shown that almost all sewages can be caused to give much more consistent and reliable results by judicious selection of the seeding material or by enrichment prior to its use. Thus, the practice of *laissez faire* seeding of dilution water should be discouraged.

There has been considerable controversy over the reproducibility of results that are possible in the B.O.D. tests. In our laboratory we do not have much difficulty in obtaining reproducibility of results on different dilutions. In fact, we have carried on investigations at high dissolved oxygen levels of 25 or 30 p.p.m. (accomplished by aeration with oxygen) to enable us to multiply the number of different dilutions used. Studies have been made with solutions of glucose, ammonium acetate, phenol, and formaldehyde. The results of these studies are given in Table II. For those who will take the trouble to plot the data or calculate the B.O.D. to some uniform basis, it will be found that the B.O.D. in all cases was directly proportional to the amount of organic matter undergoing biochemical stabilization. Phenol and formaldehyde are normally considered toxic substances, but these data show them to be nontoxic in concentrations up to and including 12 and 21 p.p.m., respectively.

A word of caution is in order for those who would try to reproduce our results or obtain similar ones on other substances. Standard B.O.D. dilution water as prepared today does not contain enough nutrient materials, mainly nitrogen, to take care of such high organic concentrations. Consequently, amounts of the nutrient elements should be increased, proportionally. In the second place, in order to determine the D.O. in samples containing 15, 20, 25, or 30 p.p.m. of dissolved oxygen, an increase must be made in the amount of reagents introduced to fix the oxygen. Also, additional KI should be added to avoid loss of iodine vapors during transfer and titration of the sample, especially with the blank samples.

The determination of the B.O.D. of pure substances can frequently lead to erroneous results and faulty conclusions unless caution is taken. An instance illustrating this situation is the

TABLE I.—5-Day B.O.D. of Primary Standards and Kier Liquor with Ward St. Sewage Seed

Organic Substrate	No. of Samples	B.O.D. (p.p.m.)		Standard Deviation	Coeff. of Variation
		Range	Mean		
Glucose	40	188 to 240	218	9.88	4.53
Glutamic acid	36	188 to 220	207.5	9.08	4.37
Kier liquor	17	11,500 to 14,300	13,000	640	4.92

TABLE II.—5-Day B.O.D. of Various Dilutions of Several Substrates Using Oxygenated Dilution Water

Glucose		Ammonium Acetate		Phenol		Formaldehyde	
Conc. (p.p.m.)	B.O.D. (p.p.m.)	Conc. (p.p.m.)	B.O.D. (p.p.m.)	Conc. (p.p.m.)	B.O.D. (p.p.m.)	Conc. (p.p.m.)	B.O.D. (p.p.m.)
4	2.70	5	2.90	2	3.50	3	2.85
8	5.20	10	5.90	4	7.30	6	5.40
12	8.30	15	8.90	6	11.10	9	8.65
16	11.40	20	11.40	8	15.05	12	11.85
20	13.90	25	15.00	10	18.80	15	14.55
24	16.30	30	17.85	12	22.50	18	18.05
28	18.90	—	—	—	—	21	21.90
32	21.50	—	—	—	—	—	—

case of the amino acid, methionine. When studied alone in pure form it exerted a 5-day B.O.D. equal to 11.2 per cent of its calculated total oxygen demand. When mixed with glucose it exhibited 59 per cent of its calculated demand. Therefore, it seems pertinent to determine the B.O.D. of highly specialized industrial wastes in combination with more complex wastes, such as domestic sewage, in order to obtain a good picture of how such wastes will behave in streams or in treatment plants handling composite wastes.

In concluding, there are a few general comments which seem in order. During the last few years a great deal has been reported concerning k values or reaction rates. The choice of a k value of 0.1 at 20° C. has worked fine for engineers in stream pollution control because it has given them, unknowingly, a safety factor which they did not anticipate.

In recent studies on B.O.D., most of which have been done with domestic sewage, it has been found that the k value during the regular incubation tests averages around 0.17 to 0.18 and ranges on occasion as high as 0.30. With such high reaction rates, by the fifth day the flat part of the B.O.D. curve has been reached. The engineer in calculating L values from 5-day B.O.D. data, therefore, obtains values considerably above those he would get if he were to use the higher values of k. Thus, in fairness, to those who are "footing the bill" in stream pollution control, it appears that the engineer should insist on k values as part of 5-day B.O.D. data, or simply ask, instead, for L values from the analyst.

Mr. Ruchhoft:—I am sure that most of us have been confused a little more by some of this discussion. A number of things have been run together here that are all of concern in this general problem. However, as I see it, three things have been discussed: first, the techniques and the difficulties of the B.O.D. test; second, the interpretation and the translation of this test to field conditions and to stream waters; and third, the possible substitution of another test.

Dr. Sawyer has done an excellent job in illustrating some of the work done in his laboratory, bringing out some of the new features, particularly with respect to standardization of this technique. However, one point he perhaps did not make clear was his introduction of a new technique when he begins to determine dissolved oxygen up to 20 to 24 p.p.m.

I am sure none of us have had any occasion to do that, except perhaps in a few cases where there is supersaturation due to an alkaloid condition. At that time some of the D.O. values are not exactly right. In ordinary work D.O. values are not very far off.

Most analysts are presently using 2 ml. of potassium dichromate. To go to the higher concentrations mentioned will certainly require more careful

manipulation to obtain all of the dissolved oxygen.

As a matter of fact, although precision has been discussed, it was shown in the work done by the National Research Council Subcommittee on Sewage Treatment what the precisions were within the five-day test at a number of places. The general conclusion probably can be reached that, with sewage at least and with stream waters, this can be assumed to be pretty close to plus or minus 5 per cent. Dr. Sawyer seems to indicate in his work that those values were confirmed. So in the ordinary test a precision of plus or minus 5 per cent can be assumed.

It has been shown by several investigators that as soon as there is any nitrification this precision decreases. This is particularly true in the incipient stages of nitrification. We seem to be on the verge of re-evaluating these techniques and considering improvements for the standard methods. The technique probably will be improved, although a number of the difficulties will have to be ironed out before the changes are actually proposed.

With regard to the interpretation as to stream conditions, many of us have realized for some time that it was not possible to take the results from the B.O.D. bottles and interpret them directly. However, the errors involved in most cases have not been too great when this was done. As Dr. Sawyer pointed out, engineers have been using such interpretations for a good many years with thoroughly satisfactory results. There have been many difficulties and we all realize that some field data are unexplainable.

I would like to go into the matter of the substitution of another test, because we have talked a lot about oxygen consumed or, as some people prefer to call it, chemical oxygen demand. Some work on comparison of oxygen consumed and B.O.D. has been done at the Environmental Health Center.

In discussing the work I would like to illustrate it with some results from a small stream near Cincinnati into which a sewage treatment plant discharges. There is a very rapid recovery because of the nature of the stream. Above the sewage plant, the ratio of oxygen consumed to B.O.D. is around 6 to 1. That is a very high ratio and may cause wonder. However, above the sewage plant the stream is very well stabilized and the organic matter is stabilized in the form of normal microfauna.

Because of that stabilization the B.O.D. is low. However, the stream contains this organic matter, which can be oxidized by chemical oxygen; consequently, the high ratio. Below the discharge from the plant the ratio becomes anywhere from 2 to 1.

Moreover, this is not constant. In other words, the picture has changed completely as we have gone downstream. This represents a very rapid recovery. The ratio changes again completely until we get stabilization, when it is back to 6 to 1.

I would like to ask how one is going to make an interpretation on oxygen consumed tests, which do not measure the oxidized organic matter biochemically, and translate that knowledge into oxygen requirements in the stream. It would seem to be a much more difficult problem to take any one of these chemical tests and make interpretations as to oxygen requirements than we have at present with our B.O.D. test.

Mr. Enslow:—What method for oxygen consumed are you using?

Mr. Ruchhoft:—We use the dichromate method of Moore. I would like to point out that at Cincinnati we have been studying six of these procedures, including the permanganate method, the present standard method, and the various modifications of the dichromate method.

Study of the precision of these procedures indicates that on a good many industrial wastes there will be no more precision than on the B.O.D. tests, and that is particularly true of the permanganate method used for the past 30 years.

INDUSTRIAL WASTE INVESTIGATIONS IN NEW YORK CITY *

By Robert Shapiro

Chief of Laboratories, Dept. of Public Works, New York City, N. Y.

New York City is engaged in a vast sewage disposal program aimed at treating essentially all of the city's wastes by 1959. This will be accomplished by 18 treatment plants in as many drainage areas. Inasmuch as the ratio of domestic to industrial wastes in each drainage area varies considerably, the most fundamental considerations of design as regards type of treatment, volumes of flow, and concentration of wastes will be appreciably affected by the industrial contributions. For example, the area draining to the Tallmans Island plant is primarily domestic and contains only a few industries, which can be individually checked. Treatment of the wastes from that area is very satisfactorily performed by the activated sludge process. The proposed Newtown Creek plant area, on the other hand, will have a proportionally large contribution from numerous industries, from which the toxic wastes may be inimical to biological treatment. It follows, therefore, that industrial surveys are essential at the design stage for sewage treatment.

An industrial listing for New York City would cover a vast variety of manufacturing and processing plants, including almost every field of endeavor except mining and large-scale farming. A partial list would cover breweries, soft drinks, food processing, chemical manufacture, dyeing, laundries, metal processing, oil refining, electroplating, bakeries, photoengraving, dairy products, ice cream, etc.

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Wastes Regulations

With good foresight, on the occasion of the revision of the New York City Charter (1938), regulations were adopted to control the kinds of wastes which may be discharged into public sewers. The terms of these regulations are of necessity broad and general.

One section refers to "Materials and Substances Excluded from Public Sewers." It lists heavy gritty materials, which might cause obstructions in the sewers; inflammable or explosive liquids or gases; various oil, grease, or paint wastes; and concentrated organic products, which may overload the treatment plants.

A following section is entitled "Materials and Substances Which May Be Discharged into Sewers Only after Approved Treatment." Under this heading are listed those industries normally discharging organic or inorganic wastes which might be corrosive, toxic to biological treatment, or produce high B.O.D. loads. The preliminary treatment process must be approved by the Commissioner of Public Works.

Violations of these regulations are subject to civil penalties. Industrial surveys, whether undertaken on an area basis or as a result of special treatment or maintenance problems, serve to check on compliance with the above regulations.

Possible Effects of Wastes

The treatment of industrial wastes that are not detrimental or do not tend to overload the works they discharge to would seem to be a proper civic function. The methods of sewage treatment

now employed (that is, grit removal, sedimentation, activated sludge or chemical coagulation, and digestion) are suitable for treating most industrial wastes. It is readily conceivable that a combination of such wastes from various industries and their addition to domestic sewage might result in a mixture more amenable to treatment than some of these wastes alone, because of dilution of toxic material, neutralization of acid or caustic wastes, mutual flocculation of colloids, breaking of emulsions, and the addition of organic matter which may more readily support biological flocs. Some instances might be found of the converse (such as the additive effects of acids, colloidal dispersion, excessive amounts of organic wastes, and increased chlorine demands). These possibilities present all the more reason for industrial waste surveys. The allocation of costs and the balancing of a policy of admitting such wastes against the benefits to be derived by the municipality through increased employment and taxes from industry are beyond the scope of this paper.

New York City does not attempt to devise treatment procedures for any particular industrial waste, although it does cooperate where requested, without certification of the efficiency or acceptance of the final treatment methods adopted and with the reservation that the operating results must still meet with the regulations previously outlined.

Aims of Ideal Wastes Survey

An ideal industrial wastes survey would supply the designing engineers with the following information:

1. The volume to be treated, including maximum and minimum flows and time of day they will occur, and seasonal volume variations.
2. The concentration of the wastes in regard to suspended solids, total and volatile, and putrescible material as determined by the B.O.D. test.
3. The corrosive character of the wastes as it may affect the sewers or plant equipment.
4. Whether there is present an appreciable amount of heavy material liable to settle in the sewers or grit chambers. This would include seeds from food processing or feed manufacturing, and sand and coal washings.
5. The possible toxic effect of the wastes on biological treatment processes, such as activated sludge and digestion.
6. The presence of other materials liable to interfere physically with settling or secondary treatment, such as mineral oils, grease, or detergents.
7. The immediate or short-term oxygen demand due to such reducing substances as sulfides, sulfites, and thiosulfates, which may affect the freshness of the sewage and the subsequent treatment.
8. The settleable fraction and the colloidal fraction, in order to predict the behavior of the settling tanks, the sludge volumes involved, and the load on the secondary system.
9. The type of sludge produced on settling and after secondary treatment as regards its density, dewatering characteristics, and amenability to digestion.
10. The effect on chemical dosage requirements where this method of treatment is used.
11. The effect on terminal chlorine demand.
12. The effect on the receiving stream (such as grease slick, dye colors, froth or foam, and, if the receiving stream is salt water, whether secondary flocculation will occur).
13. The possible interference with control tests (such as chromates on the dissolved oxygen determination, dye wastes, as interfering color, and toxic wastes on the B.O.D. determination).
14. Added to all the previous questions and perhaps modifying the answer to many of them is the possible change in reactions due to the mutual effect of various wastes on one another

and when mixed with normal domestic sewage.

Practical Adaptation

As previously stated, to obtain the answers to these questions would be ideal. The actual survey work falls short of obtaining all these data, with personnel, analytical work, and time being the limiting factors. In order to obtain accurate values for volumes and concentrations of waste from a single establishment a very large number of samples should be taken to weight hourly changes in the process, changes which may occur during the working week, changes due to season of the year, and changes in general business conditions which affect total output and employment. Because sewage is treated on the basis of the flow as received and not on the basis of a mathematical average over a period of time, composite and grab samples, if judiciously taken according to process changes, best represent what may be expected at the sewage treatment plant.

To attempt to answer some of the other questions, such as reactions on mixing with other wastes, and secondary sludge characteristics, would involve setting up prolonged research problems for each waste. This becomes impractical considering the large variety of industries involved. The effects of each industry in the general scheme of sewage treatment must, therefore, be sampled, investigated, and analyzed as an individual problem. The data obtained are judged on the basis of past knowledge and experience. Full use is made of the extensive published literature of the various wastes as regards volume and concentration to both check and supplement the data obtained.

Preparation Preliminary to Survey

In view of the large area and the number of industries contributing to each sewage treatment plant, considerable preliminary planning is required before a survey actually starts. The general pattern may be outlined as follows:

1. A detailed map is obtained indicating every building in a block, its use, and, where industrial, the firm that occupies it.
2. This is supplemented by reference to the "Industrial Directory of New York State," which lists all industries according to type of product made and the number of employees.
3. To bring these lists up to date, the classified telephone directory is consulted.
4. A list is obtained from the Department of Water Supply, Gas, and Electricity of industries using large volumes of water.
5. An additional list is obtained, from the New York State Conservation Department, of all private wells in the area.
6. Using all this information, the maps are marked to indicate industries which may be contributing large volumes, high concentrations, or toxic wastes to the collecting sewers.
7. Route maps may then be prepared for the field work.

A preliminary survey is first made and questionnaires (see Figure 1) are filled out as far as possible for the various firms listed. This permits a considerable reduction in the number of concerns that may require sampling and analytical determinations for the evaluation of their wastes. Where a number of manufacturers are engaged in the same industry, it is possible to select one or more as representative for more intensive study. On the basis of the number of persons employed, the volume of liquid wastes, and total production, it is possible to gain a reasonable estimate of the total contribution of that industry.

Most business concerns have been found to be cooperative when the nature of the survey is explained to them. A few have been apprehensive that they may be stopped from dis-

CITY OF NEW YORK

DEPARTMENT OF PUBLIC WORKS

Bureau of Sewage Disposal

TRADE WASTE SURVEY

AREA TRIBUTARY TO..... Serial No.....

1. Borough..... 2. Date.....

3. Address.....

4. Name of Occupant.....

5. Owner of Premises..... 6. Address.....

7. Nature of Business..... 8. Quantity Produced.....

9. Operation of Plant.....Hrs./Day.....Days/Wk.....Wks./Yr.....Season

10. Raw Materials Used.....

11. Number of Employees.....

12. Water Supply, Public.....Private.....River.....

13. Kinds of Waste Discharged and Quantity.....

14. Waste Treatment:

A. Type..... B. Capacity.....

C. How Often Cleaned..... D. Quantity Removed.....

E. Disposal..... (I) Effluent to.....
(II) Sludge to

15. Connection to Sewer:

Storm Water.....Roof Drain.....Catch Basin.....

16. Sample: Where Collected.....

.....Collected By.....

17. Person Interviewed.....Title.....

INSPECTOR.....

Remarks:

FIGURE 1.—Industrial waste survey questionnaire used by Bureau of Sewage Disposal, New York City Department of Public Works.

charging their wastes; some are reluctant to reveal production figures, which they fear might get into the hands of competitors. In many ways, the success of the survey and the accuracy and reliability of the results are dependent on such intangible factors as the tactfulness of the inspection staff and the forthrightness of the manufacturers' representatives.

Sampling

Special consideration must be given to such seasonal manufacturing processes as the soft drink and the ice cream industries. During their peak production they can discharge an appreciable organic load to the municipal sewers.

Most industries operate on an 8-hr. day starting at 8 A.M. Flows and concentrations cannot, therefore, be computed on a 24-hr. average, but must be considered, from the viewpoint of treatment, on the basis of peak flow and concentration, as well as total amounts. The baking industry investigations have shown very little waste discharged during the production period, but very appreciable amounts of concentrated organic wastes during the daytime period when the equipment is cleaned. Such factors, therefore, make an industrial survey more reliable when a number of periodic samples are taken and each sample is analyzed separately. Where tanks are rinsed or equipment is washed during or after a work day, the concentrated first washings must be proportioned to the subsequent diluted ones.

Measurement of flow volume frequently is difficult. Where city water is used for a single process, regular reading of the meters makes this a simple case. In many instances, however, various uses are made of the water; some is used for cooling, leaving it unchanged, and other fractions, used for direct manufacturing and cleaning, carry appreciable waste loads. These fractions usually flow through channels and pipes to a common discharge line underground. To make separate estimates of each waste and take and proportion samples is difficult under these circumstances.

Many firms using private wells and discharging their wastes to the sewers do not have means of measuring the flow. Approximations from pump ratings are used, therefore, in proportioning the samples. This may be the source of appreciable errors in the final computations.

Another example of sampling difficulties arose in a meat processing plant, where the grease trap was cleaned only when it was quite full. The amount of grease escaping to the sewer was, therefore, very variable, depending on the efficiency of the trap, which depended on its cleanliness. Any special care of the grease traps during the sampling period would distort the values as to what would be expected during customary operation.

Most simply expressed, but not simply accomplished, the sampling must be adjusted to the industrial cycle, not a periodic one.

Analyses

The individual industrial waste samples are composited or analyzed separately as dictated by the survey. Most samples are tested for B.O.D., total and volatile suspended solids, the nitrogen fractions, chlorides, alkalinity, and pH. Grease determinations, permanganate oxygen demand tests, and total solids tests frequently are made. Chlorine demand, as an indication of chemical oxygen demand, is determined on wastes from photographic establishments and chemical manufacturing industries. Special analyses are sometimes required for the presence of other materials such as chromates, cyanides, volatile solvents, and petroleum products. Where appreciable amounts of insoluble material are present, settleable solids are determined.

Calculation of Results

The final values are subject to the errors inherent in the sampling difficulties.

From the relatively complete survey of a typical plant or plants of an industry, with the information available on flows, persons employed, unit number of products produced, and the analytical results, it is possible to make an estimate of wastes produced by similar plants, and, thereby, of the total contribution of that particular industry. In this manner an estimate of the sum of the industrial wastes for an area may be made.

Similarly, an approximation of peak flows into a plant and the diurnal fluctuations may be predicted. A combination of flows of unusual concentration, toxicity, or corrosiveness may be made evident. Surveys made to date, for example, indicate that about two-thirds of the industrial waste load will arrive at the sewage plant within the 12-hr. period starting after 8 A.M., at about the same time as the peak domestic flow.

Comments on Surveys Made

The area to be served by the extension of the Bowery Bay sewage treatment plant is highly industrialized and it has been estimated that these wastes will amount to 17 m.g.d. with a population equivalent of 277,000 based on B.O.D., or 221,000 based on suspended solids. The industrial wastes will account for about one-fifth of the anticipated total flow into the new plant. Because of the seasonal variations from soft drink and ice cream plants it is expected that the industrial wastes will drop 14 per cent in B.O.D. and 7 per cent in suspended solids during the winter. These values were obtained from information from 169 industrial plants. It was estimated that included in these wastes would be about 4.5 tons of grease from the baking, dairy products, food products, laundry, glue, and rendering plants. A railroad car washing plant and the rug cleaning industry will contribute a high suspended solids load low in B.O.D. The reducing chemicals discharged from the photographic plants are equivalent to 276 lb. of chlorine per day. The combined wastes were considered suitable for treatment with domestic sewage by the activated sludge process.

In a preliminary study of the drainage area for the Newtown Creek plant, it has been estimated that the industrial waste flow will be about equal to the total daily domestic flow. As the industrial waste flow will be concentrated primarily into the daytime hours, it will exceed the domestic flow during that period of the day. In one section of this drainage area alone, there are 51 metal plating or finishing plants, 30 dyeing establishments, 2 paint and varnish producers, 10 chemical manufacturers, a gas manufacturing plant, an oil refinery, and numerous other industries producing wastes difficult to treat. It is possible that the inorganic wastes from these plants may interfere with biological treatment processes.

Some surveys were specifically made because of a particular problem arising at treatment plants already in service. Oil is frequently an offending material found in the incoming sewage at many of the treatment plants. It may come from garage wastes, fuel oil spillage, desludging storage tanks, and similar illegal or accidental occurrences. In at least two instances, when oil was traced back through the sewers, it was found to come from leaking underground storage tanks and the owners were not aware of the loss until advised by the department's inspectors.

As has been reported by Edwards and Nussberger (1), chromate wastes from a metal processing plant were conscientiously removed by a commercial scavenger, who then, apparently dumped them into a convenient sewer. These wastes, on reaching the Tallmans Island plant, caused an appreciable upset in the treatment process.

Special and extensive investigations were made of some dye wastes interfering with the activated sludge process. The inhibiting effects of these wastes were indicated experimentally by the diminished ability of the activated sludge organisms to utilize glucose as the concentration of dyestuffs increased. By this means it was shown that if the industrial plant were to store its wastes and discharge them slowly, instead of in concentrated slugs, the treatment plant could handle these products with impunity.

In cooperation with the Department of Hospitals, investigations are being planned to determine the extent of radioactive wastes which may reach the Wards Island plant from some of the hospitals using such isotopes for treatment and research.

Industrial waste investigations are an essential adjunct to the design and operation of sewage treatment plants.

Acknowledgment

The surveys mentioned were made under the direction of G. P. Edwards, formerly chief of laboratories, New York City Dept. of Public Works. The data from the Newtown Creek area were compiled by L. R. Setter, formerly principal chemist of the department.

References

1. Edwards, G. P., and Nussberger, F. E., "The Effect of Chromate Wastes on the Activated Sludge Process at the Tallmans Island Plant." *Sewage Works Jour.*, **19**, 4, 598 (July, 1947).

DISPOSAL OF OIL FIELD WASTE WATERS

Disposal of oil field waste waters is a necessary but costly operation, which nevertheless is a part of the cost of producing oil. How this problem is handled in two California areas was described briefly by William Graham, of the Richfield Oil Company, at the 1950 Annual Meeting of the California Sewage Works Association, held in Long Beach, Calif., May 3–6, 1950.

The Santa Fe Springs Waste Water Disposal Company is a non-profit organization maintained and operated by the participating oil producers on the basis of weir measurement of each contributed flow. The plant receives each day approximately 100,000 bbl. of oily waste water, which contains salt, minerals, bacteria, and mud. The oil content averages 100 bbl. per day. Treatment consists of aeration, lagooning, flocculation with aluminum sulfate and activated sodium silicate, and screening through magnetite filters. The effluent has the following analysis: oil content, 15 to 20 p.p.m.; turbidity, 50 p.p.m. or less; total dissolved H_2S, 1.0 p.p.m. or less; and no objectionable odor. Recovered oil is marketed to help pay plant expenses. Plant investment is about $900,000 at Santa Fe Springs, and about $300,000 at the Orange County plant.

Oil Operators, Inc., a similar organization serving more than 200 separate oil producers in and around Long Beach, handles about 60,000 bbl. of waste water per day, containing an average of some 200 bbl. of petroleum emusion. After 48 hr. quiescent retention in lagoons, the oil, which includes about 20 per cent by volume of emulsified water, is skimmed. Treatment of the recovered oil includes heating in the presence of chemical additives to free it of water, after which it is satisfactory for marketing. Investment in the Long Beach-Signal Hills plants amounts to about $400,000.

Stream Pollution

INVESTIGATION OF POLLUTION OF PORT GARDNER BAY AND SNOHOMISH RIVER ESTUARY

By E. F. Eldridge and G. T. Orlob

Director and Chief Engineer, and Survey Engineer, respectively, Washington Pollution Control Commission, Olympia, Wash.

A survey of water conditions in Everett Harbor and the lower Snohomish River was undertaken by the Washington Pollution Control Commission during the months of September, October, and November, 1949. This survey involved a determination of the effects of the discharge of domestic sewage from Everett, Wash., a city of about 33,000 population, and industrial wastes, especially the discharge from two sulfite pulp mills and one soda pulp mill.

The major water use in this salt-water bay and brackish-water estuary is the support of a large existing and potential commercial and sports fishery. The Snohomish River is one of the major rivers of Puget Sound used by migrating salmon for spawning. Estimates by the State Fisheries Department show that the river is capable of producing an annual take of $1,300,000 worth of salmon, if fully developed. The Bay area is extensively used by commercial fishermen and sportsmen.

Another important water use is recreation, such as boating and bathing. Everett is in the heart of Washington's recreation areas and has much to attract its full share of the state's $125,000,000 tourist industry. It is important, therefore, to the economic welfare and health of this community to maintain the beauty and charm of the surrounding waters.

Pollution in the estuaries of a stream used by migrating types of fish may be of such a type or quantity as to form a barrier to migration and thus reduce the fisheries value of that stream. Except for a long oxygen depletion block, the adult fish on its way to the upper portions of the river is usually strong enough to surmount this barrier. The small fingerlings, however, swim largely in the surface waters and work their way gradually downstream to the estuary. Here they may remain several months adapting themselves to the transition from fresh to salt water. Pollution barriers in the estuaries at this time may destroy innumerable numbers of these small fish, which, if they matured, would greatly add to the economic value of the waters of the area.

Such a pollution barrier is found to exist in the Snohomish River and will be the principal factor demonstrated by this discussion of the Port Gardner Bay and Snohomish River survey.

The Lower River and Bay

The Snohomish River divides into three branches as it enters its delta lowland several miles above Everett. The main branch flows generally northward along the eastern city limits, turns toward the west to form the city's northern limit, and thence south through an artificial dredged canal into Port Gardner Bay. Thus, the river forms almost three sides of the area occupied by the city (see Figure 1).

Port Gardner Bay is a deep water anchorage off the Everett waterfront,

which is capable of accommodating ocean-going transport vessels. This harbor communicates with Possession Sound, which is bounded by the mainland on the east and Whidby Island on the west, and opens to Puget Sound on the south and to Port Susan and Saratoga Passage at the north.

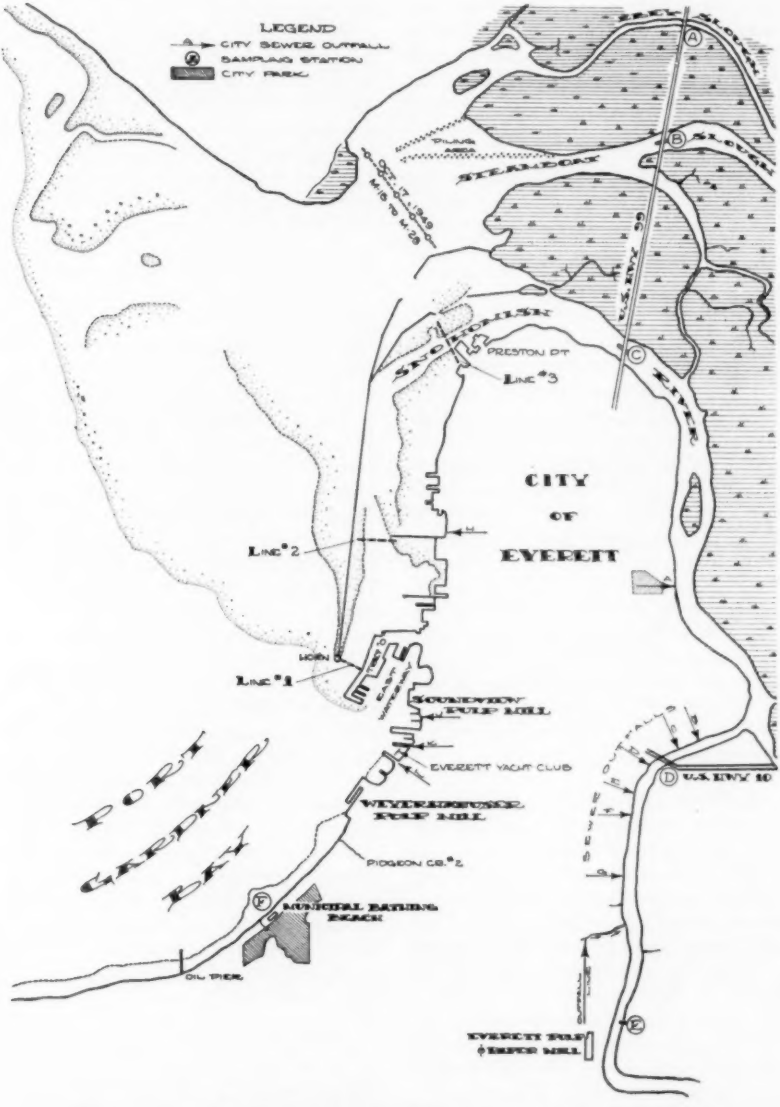

FIGURE 1.—Area covered by 1949 pollution survey of Everett Harbor and lower Snohomish River.

In order to supplement Everett harbor facilities, a waterway, known as East Waterway, was dredged along the shore near the mouth of the Snohomish River as it discharges into Port Gardner Bay and the dredged material used to form a fill, referred to as "Tract O," between the river channel and the waterway. The waterway has an average depth of approximately 30 ft. below M.L.L.W. and was used during World War II to accommodate ships undergoing repair and for the launching and final outfitting of new vessels. Everett Shipbuilding, Inc., which now occupies all of Tract O, has no new construction underway at present and does only a small amount of repair work.

The east side of the waterway is occupied by Soundview Pulp Company, the Union Oil Company pier, and the New England Fish Company. Outside the waterway and to the south are the docking facilities of the Port of Everett (Piers 1 and 2) and the moorage of the Everett Yacht Club. Finally, at the southern extremity of the industrial area is the pulp mill of the Weyerhaeuser Timber Company.

Along the shoreline southward are the city's Municipal Bathing Beach (1.5 mi. from the foot of Hewitt Avenue) and the town of Mukilteo (about 3.5 mi. distant).

Equipment and Techniques

An 18-ft. inboard motor launch was used for the collection of samples. This boat was operated by two persons, one piloting the craft and recording survey data, and the other performing the actual sampling. Shallow draft and easy maneuverability of the boat facilitated the collection of samples in the most difficult locations. Laboratory facilities were available in the Pollution Control Commission's mobile laboratory truck, which was parked near the Everett Yacht Club.

The collection of samples was accomplished using a standard water sampler, allowing a three-fold displacement of the contents of three sample bottles. All analyses for dissolved oxygen, B.O.D., pH, and chlorinity were performed in accordance with the standard procedures.

Spent sulfite liquor (S.S.L.) * concentrations were determined, using a modification of the Pearl-Benson test for nitroso-lignins. The modification consisted of the use of a photoelectric comparator (Lumetron, model 402E) for the comparison of color developed in the standard test. This instrument was found to be sensitive to 5 p.p.m. of digester strength liquor (0.5 p.p.m. S.S.L. solids). All determinations in this survey are reported in p.p.m. of concentrated digester liquor (10 per cent total solid material). Concentrations determined at less than 10 p.p.m. are reported as "trace."

Bottom samples were collected with a small clamshell dredge, operated from a boom suspended over the side of the boat. Samples were examined for odors, physical characteristics, and the existence of marine life at the time of sampling. Percentages of ash and volatile matter were determined in the laboratory, using the standard procedure for analysis of sludge and muds.

Float studies were employed on occasion to detect prevailing current directions. Such information was used only as an adjunct to data secured from collection and analysis of water samples. The floats used were designed to minimize the effects of wind action and were found on several occasions to move into or across the prevailing wind when the current moved in such a manner. A pendant with vanes to catch current motion and prevent a streamlining effect was attached to the suspending float and could be adjusted to hang at variable depths.

* In the pulp and paper industries the old term "sulfite waste liquor" (S.W.L.) has given way to the more descriptive term "spent sulfite liquor" (S.S.L.). Therefore, the latter term has been used wherever possible throughout this paper.—Ed.

Sources of Industrial Pollution

A wide variety of waste materials originating from industrial processes or operations is discharged daily to the lower Snohomish River and to Everett Harbor. The more important sources of industrial wastes which may contribute to pollution of receiving waters within the area surveyed are described briefly as follows:

Sulfite Pulp Mills

Two sulfite pulp mills are situated on the Everett waterfront near the mouth of the Snohomish River. These two plants produce a total of 875 tons of bleached sulfite pulp daily. In the processing of the timber, approximately 40 to 45 per cent of the wood is recovered as pulp, the remainder being dissolved in the acid cooking liquor and wasted to Port Gardner Bay. One of these mills discharges approximately 45 m.g.d. of waste waters, containing about 1 m.g. of concentrated spent sulfite liquor. The other mill disposes of approximately 25 m.g.d. of waste water, containing about 0.5 m.g. of S.S.L. Both mills discharge considerable quantities of white water and wastes from other minor sources.

Soda Pulp Mill

A soda pulp mill is situated above Everett on the Snohomish River and produces wood pulp and book paper from raw and scrap timber and waste paper stock. The plant uses an alkaline cooking process with a recovery system permitting the recovery of used chemicals. Waste materials resulting from this process may include waste fiber, bleaching water, and small quantities of dilute cooking liquor removed in a reverse washing system. The average 5-day B.O.D. of the waste material is approximately 180 p.p.m. and the pH ranges from 8.5 to 9.5. Approximately 6 m.g. of waste material is discharged daily through a single outfall emptying into a ditch, which ultimately reaches the Snohomish River at a point about 7 mi. above its mouth in Port Gardner Bay.

Other Industries

Three fish canneries processing about 5,000,000 lb. of salmon, halibut, cod, and bottom fish, as well as some crabs, discharge water and offal spillage into the bay and river. In most cases, offal from the processes is collected and sold to mink farms. Two meat packing plants, five dairies, and 13 lumber and shingle mills also discharge wastes to the waters in the area.

Sulfite Liquor Pollution *vs.* Oxygen Depletion

The encroachment of the polluted salt water from Port Gardner Bay into the dredged river channel, thus hampering the natural passage of migratory fishes, was the first problem to be considered in this survey. In order to secure information regarding the pollution of this channel and the possible pollution of the other two river channels, several sampling locations were selected.

Five sampling points were selected on bridges over the three channels of the Snohomish River, from its mouth in Port Gardner Bay to a point above Everett. Samples secured in the dredged channel were taken at several points across the breadth of the channel and at varying depths, depending on the conformation of the river bottom. Typical cross-sectional profiles were determined by sounding and sampling points selected at points at greatest depth, generally near midstream and near the right and left banks. (Bridge sampling points are indicated by A through E and sectional points by Lines 1, 2, and 3 and in Figure 1.) Sampling points were also selected in the bay and inner harbor.

Although the water at the mouth of the river is a dilution of salt and fresh water even at the lowest stages of the tide, a flooding tide greatly increases the percentage of saline water until at high tide the water at the river mouth is almost identical in characteristics to

that of Port Gardner Bay. As might be expected, when flooding commences the denser salt water moves upstream along the bottom, while the fresh water proceeds downstream at the surface. At the maximum rate of flood the river current is completely reversed on both top and bottom and a solid front of polluted salt water moves into the channel. The fresh river water is forced back and begins to fill the upstream end of the tidal prism, diluting the salt water it contacts, thus reducing the concentrations of pollutants in the salt water and raising the over-all level of dissolved oxygen at a distance from the channel mouth.

All samples collected within the survey areas were analyzed for the presence of sulfite liquor, as well as dissolved oxygen. Although there is no scientific information yet available to indicate that S.S.L., when accompanied by satisfactory oxygen conditions, may be detrimental to marine life, the concentration of spent sulfite liquor present is a good index to the degree of pollution. There is considerable cor-

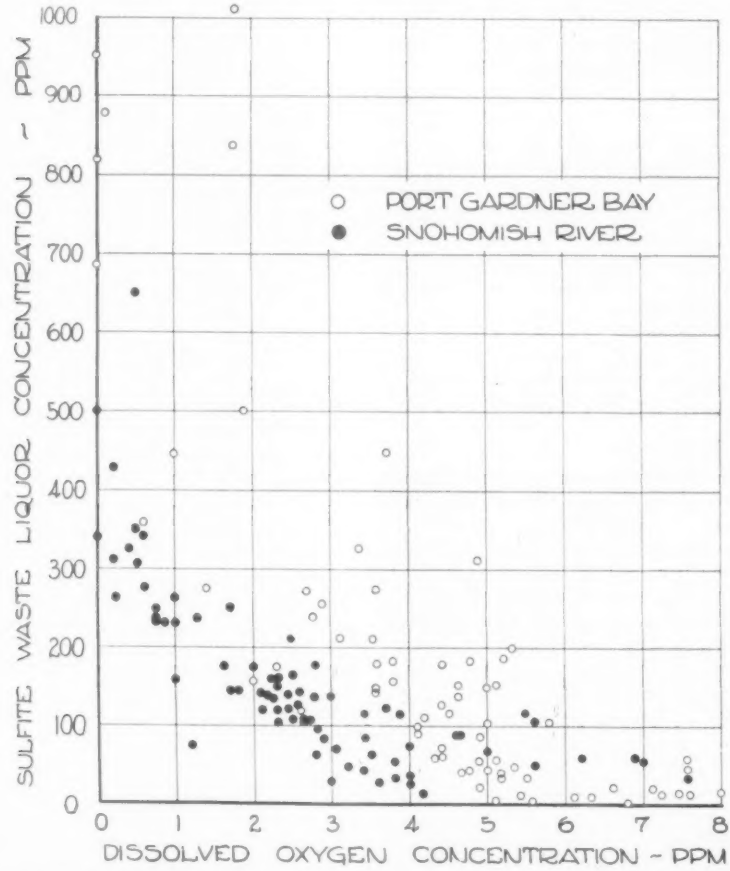

FIGURE 2.—Relationship of D.O. and S.S.L. concentrations in samples collected in Port Gardner Bay and Snohomish River.

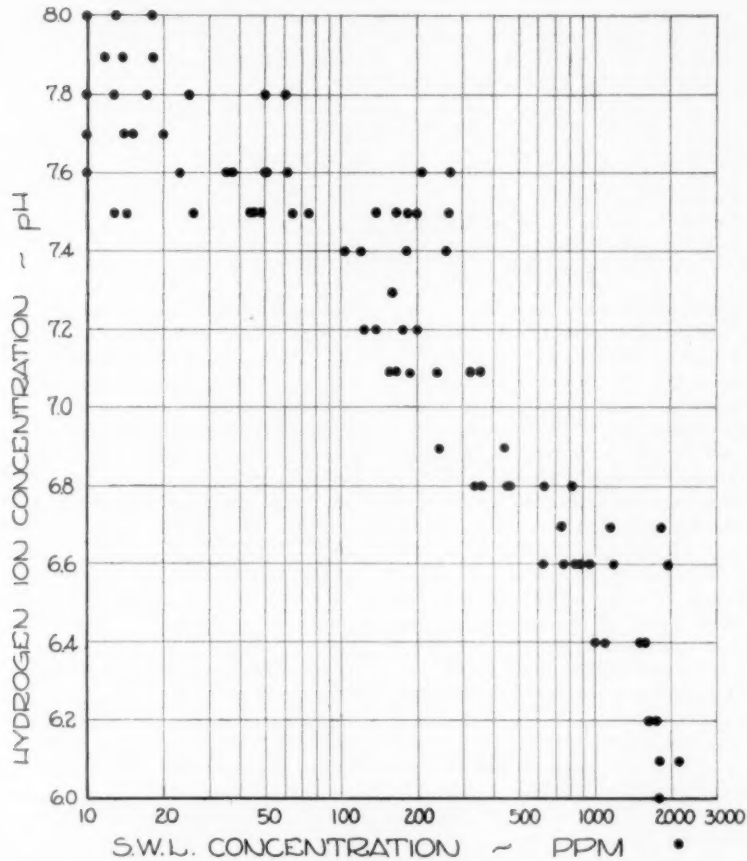

FIGURE 3.—Relationship of S.S.L. concentrations and pH values in samples collected in Port Gardner Bay.

relation between the nature of oxygen conditions in a natural water and the occurrence of S.S.L. Great reductions in oxygen concentration of the water in Port Gardner Bay and the dredged channel of the Snohomish River were always accompanied by high concentrations of S.S.L., the amount of reduction below normal conditions being somewhat proportional to the amount of S.S.L. present. These relations are shown in Figure 2, where D.O. is plotted against sulfite liquor concentrations for some 145 samples collected in the survey area. Figure 3 illustrates a similar correlation of pH and S.S.L. concentration, but the reduction in pH does not have the same significance as that of dissolved oxygen.

Spent sulfite liquor, if it remained within the confines of the river channel for a considerable period of time (up to 18 hr. under certain tide conditions), exerted a considerable demand on the available oxygen present in the already seriously depleted salt water. Oxygen removed from the waters of the Snohomish River channel

TABLE I.—Summary of Dissolved Oxygen Conditions in Snohomish River Channel

Location	Number of Samples	Per Cent of Samples[1]				
		1 P.P.M.	2 P.P.M.	3 P.P.M.	4 P.P.M.	5 P.P.M.
Line 1	71	25.4	35.2	63.4	84.6	92.9
Line 2	17	0	0	29.4	41.2	58.8
Line 3	8	0	12.5	62.5	62.5	62.5
Station C	27	0	0	18.5	25.9	37.0
Station D	19	0	0	0	0	0

[1] Per cent of samples containing equal or less D.O. than the indicated concentration.

was restored to some degree by surface reaeration due to wind and wave action and by dilution with oxygen-laden river water. At times of low river flow, dilution of polluted salt water was of negligible consequence in restoring dissolved oxygen to the level of concentration required to sustain fish life.

Confining the S.S.L. within the river channel resulted in extremely low dissolved oxygen concentrations as compared to S.S.L. concentrations. Those samples collected in Port Gardner Bay in open water, on the other hand, generally contained more oxygen for a given concentration of S.S.L.

During the course of the survey, data were secured from water analysis of samples collected at the various stations on the river channel. A summary of this information (Tables I and II) reveals that, with regard to dissolved oxygen conditions, the area in the immediate vicinity of the channel mouth at Port Gardner Bay was continually unsuitable for the sustenance of fish life. This area, in effect, constituted a barrier to the natural migration of salmonoid fishes.

Figure 4, showing the degree of oxygen depletion in the various areas of Port Gardner Bay and the three channels of the Snohomish River, effectively indicates the oxygen block over the main channel of the river. Figure 5 shows areas of S.S.L. concentrations.

On September 29, 1949, an intensive survey was conducted at Line 1 (Figure 1) across the Snohomish River mouth. Sampling commenced with the flooding tide and continued through the maximum flood and the succeeding ebbing tide. Dissolved oxygen and S.S.L. concentrations were determined for samples collected at the surface, mid-depth, and bottom from locations near the right and left banks and at mid-stream. Water conditions during the

TABLE II.—Summary of S. S. L. Concentrations in Snohomish River

Location	Number of Samples	Per Cent of Samples[1]						
		50 P.P.M.	100 P.P.M.	150 P.P.M.	200 P.P.M.	300 P.P.M.	400 P.P.M.	500 P.P.M.
Line 1	71	88.8	70.4	43.7	29.6	14.1	5.6	4.2
Line 2	17	76.4	52.9	5.9	0	0	0	0
Line 3	8	75.0	62.5	50.0	0	0	0	0
Station C	26	53.8	30.7	8.7	3.9	0	0	0
		Trace	10 P.P.M.	20 P.P.M.	30 P.P.M.	50 P.P.M.	100 P.P.M.	150 P.P.M.
Station D	18	50.0	5.6	5.6	0	0	0	0
Station B	24	79.2	37.5	20.8	16.7	8.3	8.3	0
Station A	10	30.0	10.0	0	0	0	0	0

[1] Per cent of samples containing equal or greater S. S. L. than indicated concentration.

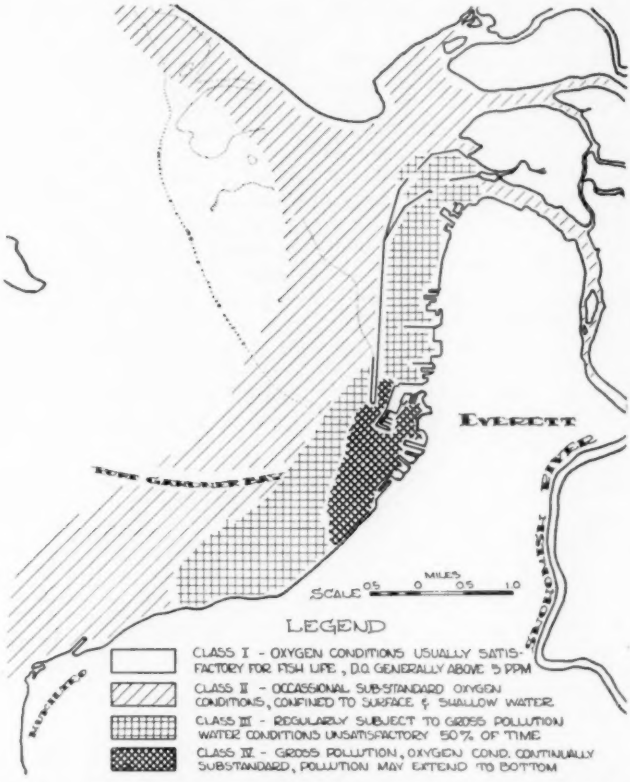
EVERETT
PORT GARDNER BAY
SNOHOMISH RIVER
SCALE .05 0 .05 1.0 MILES
LEGEND
CLASS I - OXYGEN CONDITIONS USUALLY SATISFACTORY FOR FISH LIFE., D.O. GENERALLY ABOVE 5 PPM
CLASS II - OCCASSIONAL SUB-STANDARD OXYGEN CONDITIONS, CONFINED TO SURFACE & SHALLOW WATER
CLASS III - REGULARLY SUBJECT TO GROSS POLLUTION WATER CONDITIONS UNSATISFACTORY 50% OF TIME
CLASS IV - GROSS POLLUTION, OXYGEN COND. CONTINUALLY SUBSTANDARD, POLLUTION MAY EXTEND TO BOTTOM

FIGURE 4.—D.O. conditions in Port Gardner Bay and lower Snohomish River.

survey, covering a period of approximately 12 hr., are shown in Figure 6 and Table III.

Tides of the Puget Sound Basin, such as those occurring daily at Everett, are of the mixed type, consisting of one extreme ebbing-flooding cycle and one cycle of lesser magnitude approximately each lunar day. The above-mentioned study began at the lower low tide for the day in question and proceeded through to the succeeding high-low tide. A minor flood tide and a strong ebb followed. Intolerable conditions are shown to have existed throughout a 12-hr. period and it is likely that such conditions would remain throughout the following minor

TABLE III.—Oxygen Conditions at Snohomish River Mouth, Sept. 29, 1949

Location	Per Cent of Samples[1]				
	1 P.P.M.	2 P.P.M.	3 P.P.M.	4 P.P.M.	5 P.P.M.
Line 1	34.0	47.2	71.7	96.2	100.0

[1] Per cent samples containing equal or less D. O. than indicated concentration.

flood tide and during the first stages of the tidal recession.

Although poor oxygen conditions were found to extend upstream on a flooding tide to 3.5 mi. from the channel mouth, sulfite liquor was detected in significant concentrations as far as 5 mi. upstream from the sources of pulp mill pollution in Port Gardner Bay.

Tidal Effects

It was apparent during the survey that the entire daily discharge from a single sewer or pulp mill was not entirely removed from the outfall location and replaced by fresh water, but that some of the waste may remain in the area indefinitely. The character of local tidal movements along the Everett waterfront indicated that sewage and sulfite liquor, although they may be carried southwest along the shoreline on one stage of the tide, may be returned on a subsequent tidal stage. For this reason, concentrations of the waste are increased and an added burden is placed on the receiving water in the vicinity of the outfall.

During the course of the current study, the outfalls of the sulfite mills were observed to be discharging sulfite liquor and white water at what appeared to be normal capacity. Sporadic kills of small fish were noted throughout the area southwest toward

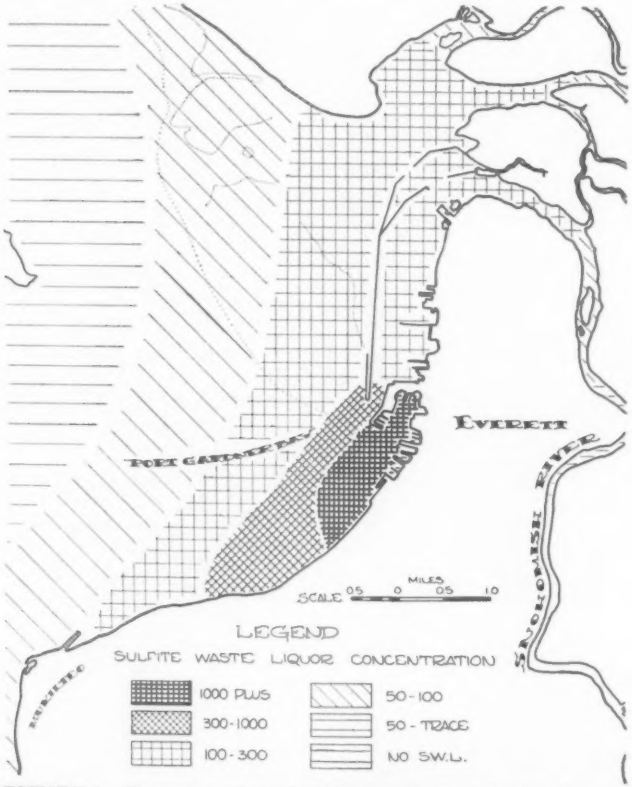

FIGURE 5.—Occurrence of spent sulfite liquor in Port Gardner Bay and lower Snohomish River.

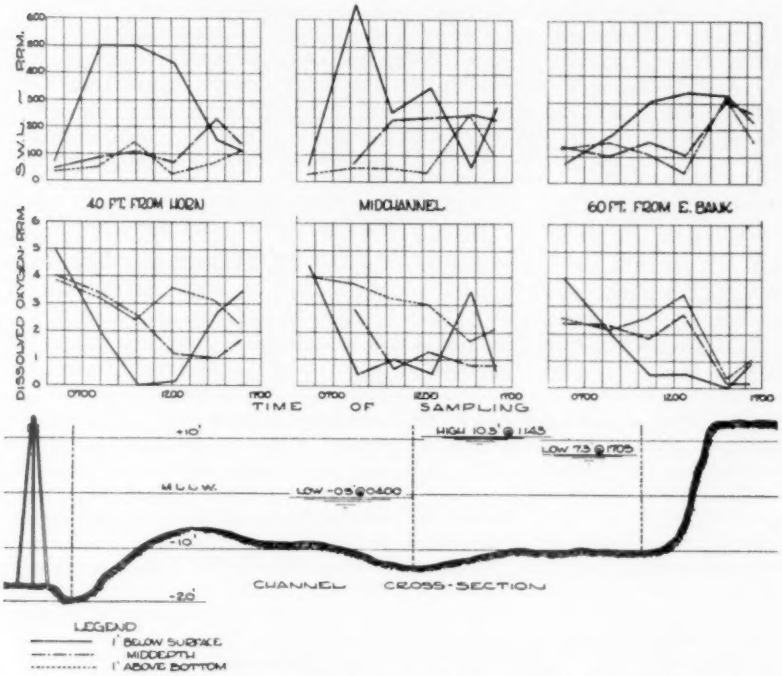

FIGURE 6.—D.O. and S.S.L. conditions at the mouth of the Snohomish River on Sept. 29, 1949.

Mukilteo, and sulfite liquor was very much in evidence in the water. For several hours after the release of floats, samples were collected at various points and at several depths in the area. Data for these samplings, which included determinations of S.S.L. concentrations, D.O. concentration, and pH, are summarized in Table IV.

Fish Kills in Everett Harbor

The destruction of fish and marine life as a result of the pollution load placed on Everett Harbor has been reported on numerous occasions by local residents, but seldom has sufficient information been obtained to indicate the exact cause, the extent of the kills, and the types of fish involved.

During the course of this investigation of Everett Harbor pollution, the survey party was afforded several opportunities to observe kills of fish. On these occasions notes were taken on the time, location, and extent of the kill and the types of fish affected, and samples of water were secured for analysis.

Extensive kills occurred on September 28 and during the afternoon of September 29, 1949. The latter involved not only herring, candlefish, and small scrap fish, but fishes of the salmonoid type. This kill persisted for approximately 5 hr. and was noted to some degree over the entire inner harbor. Some small fish were noted on the surface of the water, but owing to the large numbers of scavenger gulls, no reliable estimate of the numbers of fish involved could be made. During the period of observation, several hundred small fish were noted in the mouths of gulls repeatedly diving

TABLE IV.—Summary of Oxygen Conditions; Survey of October 13, 1949

Depth	Number of Samples	Per Cent of Samples[1]				
		1 P.P.M.	2 P.P.M.	3 P.P.M.	4 P.P.M.	5 P.P.M.
All samples	34	41.2	47.1	52.9	64.7	79.3
Surface to 5 ft.	20	65.0	75.0	85.0	100.0	100.0
15 ft., bottom, or deeper	14	7.1	7.1	7.1	14.1	50.0

[1] Per cent of samples containing equal of less D. O. than indicated concentration.

and arising from the water surface. Two large fish were observed to be in obvious distress. One, a salmon about 2 ft. in length, was observed at close range. This fish repeatedly jumped, gasped, and swam erratically in circles. Finally tiring, it was last noted on its side, gradually sinking to the harbor bottom.

At the location where the salmon was observed, a sample was taken 1 ft. below the water surface and tested for dissolved oxygen. Results indicated that water at the sampling point contained but 0.1 p.p.m., merely a trace of dissolved oxygen. Throughout the period when the fish kill was observed, 27 samples were taken. The greatest dissolved oxygen concentration for these samples was 3.6 p.p.m., with 18 of the samples containing less than 2.0 p.p.m. and 11 showing less than 1.0 p.p.m. Spent sulfite liquor concentrations for the same period reached a maximum of 430 p.p.m., with 77.8 per cent showing concentrations greater than 100 p.p.m.

The movement of the tidal prism during the day in question suggests a possible explanation for the existence of such a large quantity of oxygen-depleted water. Lower low water for the day occurred at 4:00 A.M. at a level of − 0.5 ft. The subsequent flooding tide tended to prevent the escape of polluted waters from the bay, forcing these waters to supply the continuing demand for oxygen of the S.S.L. and sewage present. Higher high water was reached at 11:43 A.M., just prior to the first observation of the fish kill, cresting at a height of 10.3 ft. The following ebb tide, which allowed a decline in the level of the tidal prism of only 3 ft. in 5 hr. and 12 min., prevented a nominal exchange of polluted water for water of higher dissolved oxygen content. At the same time, the already seriously depleted water of the inner harbor was required to continue carrying the burden of oxygen demand. The whole harbor front, under such conditions, must have become nearly devoid of oxygen, thus imperiling the existence of fish within, or subsequently entering, the area.

Numerous other fish kills of like character but of lesser degree were observed during the course of the survey. Undoubtedly, others occur which are not observed. Kills of salmonoid types of fish are not as likely to be seen as those of herring and candlefish, as the dead salmon sink to the bottom. Gulls are always present in large numbers in case of herring kills, making observations of the extent of the kills difficult.

Pollution by Domestic Sewage

Much has been said previously herein about the effects of pulp mill waste pollution, as this is the predominating waste in the area. However, almost the entire population of Everett, (estimated at 33,000) is served by combined sewers, which carry sanitary waste as well as storm-water runoff to 11 major points of discharge in the Snohomish River and Port Gardner Bay. Seven of these outfalls, serving approximately 75 per cent of Everett's population, discharge directly to the Snohomish River near its west bank along

1.5 mi. of river front. Sewage from these outfalls, moving back and forth with changes in river current resulting from tidal action, ultimately reaches Port Gardner Bay through the dredged channel.

To establish the degree of contamination of the river water by domestic sewage, bacteriological samples were taken periodically during the course of the survey from each of three locations along the river. One of these sampling stations was established near Lowell, upstream from the first Everett sewer outfall to the river. The town of Lowell is unsewered and the only domestic sewage reaching the river in this vicinity originates from residences and businesses along the river bank. A second sampling station (Station D) was located at the foot of Hewitt Avenue, the sample being collected from the U. S. Highway 10 bridge, and a third station (Station C) was situated at the U. S. Highway 99 bridge below the last sewer outfall from the eastern slope of the city.

All samples collected during the survey were handled in accordance with standard procedures, the inoculations being performed immediately following collection. Results were reported as the most probable number (M.P.N.) of coliform organisms per 100 ml.

Results of bacteriological analysis, together with appropriate data regarding collection of samples, are shown in Table V and Figure 7. Considerable variation in determinations is noted in a summary of samples taken from the three river stations. The mean coliform index increased from 1,550 per 100 ml. at Station E, to 10,900 per 100 ml. at Station D, and 30,300 per 100 ml. at Station C. Median counts do not reflect such marked variations, indicating 2,300 per 100 ml. for Station E and 6,200 per 100 ml. for each of the two lower stations.

There are a number of factors which may influence the results of samples collected. At those stations appreciably affected by tidal currents, notably Station C, extreme variations in the bacteriological counts are noted. Periodic reversals in current direction, where the current actually moves upstream, cause impounding of polluted water with some dilution from advancing salt water. Succeeding ebb tides may allow free movement of the polluted water seaward.

A large number of the samples was collected at times of high river flow when concentrations of sewage were appreciably reduced by dilution in the river and in the contributing combined sewers. Although this sanitary survey of the river revealed very unsatisfactory conditions, a dry-weather survey no doubt would disclose the most extreme sewage pollution. During the summer months domestic wastes would normally be very concentrated, as they would reach the river undiluted by large amounts of storm-water runoff and the river flow would be low.

The inner Everett Harbor, including the East Waterway and the docking areas near Piers 1 and 2, receives the discharge from five combined sewers draining the western slope of the city.

TABLE V.—Summary of Bacteriological Data, Everett Survey

Sampling Station	Total Number Samples	Per Cent of Samples[1]				M. P. N.[2]			
		50	500	1,000	3,000	Max.	Min.	Med.	Mean
City Beach, F	23	95.7	78.3	47.8	4.3	24,000	23	620	2,260
Lowell, E	7	100.0	85.5	57.2	0.0	2,400	230	2,300	1,550
Highway 10, D	11	100.0	100.0	100.0	81.7	24,000	2,300	6,200	10,960
Highway 99, C	12	100.0	100.0	100.0	66.7	240,000	2,300	6,200	30,300

[1] Per cent of samples indicating M. P. N. greater than value designated.
[2] Coliform organisms per 100 ml.

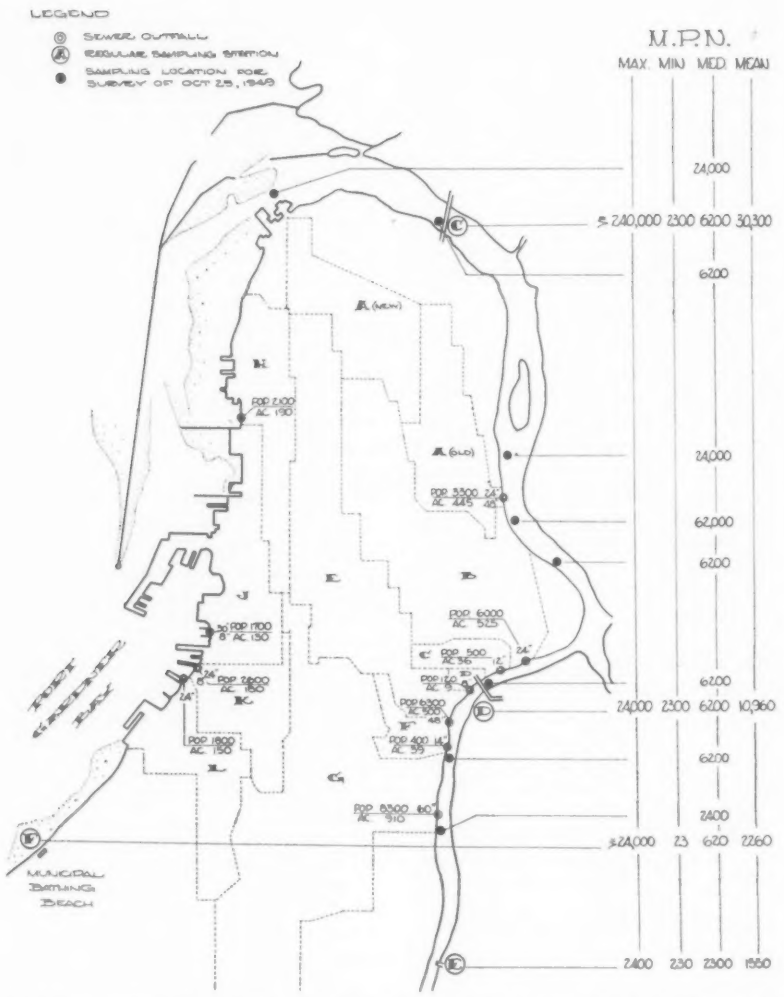

FIGURE 7.—Results of bacteriological survey of Sept.–Nov., 1949, showing sewer outfalls, drainage areas, and their effects on M.P.N.'s in the Snohomish River.

These sewers, discharging at three separate outfall points situated in relatively stagnant areas, serve an estimated population of 6,000. The adequate dispersion of sewage throughout the receiving water from the outfalls in their present locations is a problem of some concern. Disposal of sewage by dilution is theoretically dependent on the action of tidal currents for the distribution of the wastes throughout such a large volume of the receiving water that it ceases to exist as a menace to public health or as a general nuisance. There are a number of factors, however, which may decrease the theoreti-

cal efficiency of such a method for disposal and render it fundamentally impractical.

Domestic sewage, having a specific gravity very nearly the same as fresh water, rises to the surface of the denser salt water upon issuing from the outfall. Some mixing takes place by the time the material reaches the surface, the degree of mixing being somewhat a function of the depth at which the outfall discharges. At low tidal stages the effect of mixing during the vertical rise is minimized and in some instances when the outfalls are exposed by low tides, concentrated raw sewage may pour out onto the beach or the surface of the water. Such conditions were noted at all outfall locations in the inner harbor and in particular at outfalls J and K (Figure 7), which are frequently subject to exposure by receding tides.

Sewage materials, upon reaching the surface somewhat dispersed, must then be carried away from the outfall by tidal currents. As the diluted waste moves with the tide, some lateral as well as vertical diffusion occurs when the sewage is tumbled about by a complexity of currents, and the solid particles begin to settle to the harbor bottom. While one tidal motion may carry the waste material away from the discharge location, a subsequent tide may return the material to its point of origin. Samples taken for bacteriological analysis at the municipal beach to the southwest of Everett usually reveal that higher concentrations of coliform organisms are evident following a flooding tide than after an ebbing tide. A total of 23 bacteriological samples were collected at the city beach during the course of the survey, with 78.3 per cent of the samples showing M.P.N.'s greater than 500 per 100 ml. and 47.8 per cent greater than 1,000 per 100 ml. A maximum count of 24,000 was recorded on one occasion; the mean count for the 23 samples was 2,260 per 100 ml.

Summary

The waters of Port Gardner Bay and the lower Snohomish River, in addition to supporting a large commercial and sports fishery, have exceptional recreational values. A pollutional barrier has been demonstrated to exist in the estuary of the south branch of this river. The barrier is caused by the discharge of industrial waste from two sulfite pulp mills and municipal waste from the city of Everett. Numerous large kills of herring, candlefish, young salmon, and other types of fish have occurred, due primarily to low oxygen conditions, and perhaps to some unproven toxicity. Tides carry pollution from the inner harbor across the mouth of the river and, at times, up the stream for a considerable distance. Young salmon migrating seaward must spend several months in the estuary adapting themselves to salt water and are caught in the pollutional barrier.

River frontage on the Snohomish and beach areas on the Bay are undesirably affected by sewage pollution. High bacterial counts and the presence of sewage solids will tend to depreciate property values and retard recreational developments unless correction of the municipal problem is accomplished.

SEMI-AUTOMATIC WATER, SEWAGE, AND INDUSTRIAL WASTE SAMPLER

By Ralph Stone and Perry M. Teeple

Respectively, Sanitary Engineer, University of California, Los Angeles, Calif., and Sanitary Engineer, Florida State Board of Health, Jacksonville, Fla.

An improved bacteriological and chemical sampler with several novel features was developed by the authors to meet the need for a device that would give uniform sampling procedure and an automatically self-sealing sampler for any working depth. Three of the devices built in 1945 have given satisfactory service on the St. Johns River pollution survey and on other stream pollution and water sampling surveys. The apparatus has provisions for simultaneously obtaining a bacteriological sample, a B.O.D. sample, a D.O. sample, and enough extra fluid (in the body of the container) to supply a 1-gal. chemical analysis sample (Figure 1).

The novel feature in the design of the sampler is the use of a $\frac{5}{8}$-in. marble sphere air valve, which prevents entrance of fluid until the protective cap covering the inlet to the container body is opened. This action automatically permits samples of water to be taken at any particular depth, or by vertical

FIGURE 1.—Sampler simultaneously collects B.O.D., D.O., and bacteriological samples, as well as extra fluid for 1-gal. chemical analysis sample.

movement of the sampler, composite depth fluid sampling can be performed. In addition, once the protective cap uncovers the sampler inlet tubes, the various containers fill up with fluid until the inflow is cut off automatically by the air release tube, which extends 1¾ in. below the lid surface.

Sampler Details

Essentially the sampler (Figures 2 and 3) is a bronze cylinder of 8½-in. internal diameter and 8⅛ in. tall without the lid on. A bronze lid 9¼ in. in diameter and 3/16 in. thick has a ¾-in. tall neck brazed on at the center. This neck is of 2¾-in. outside diameter at lid level and is slightly tapered upwards.

FIGURE 2.—Semi-automatic deep-water sampler with cap removed (left) to show raised neck containing sterile bacteriological sample tube and central inlet orifice. Air release tube with marble sphere valve is at right.

The neck has two orifices—one, of ⅝-in. diameter, receives the rubber stopper pierced by a sterile tube; the other, of ⅜-in. diameter, is connected by a copper tube to a manifold of two ¼-in. inside diameter copper tubes that project down into two 300-ml. D.O. bottles. The 5-in. long sterile tube passes down into a 4-oz. (or 125-ml.) sterilized bacteriological sample bottle.

A sheet metal frame soldered to the cylinder wall holds the two D.O. bottles in place laterally; they rest on a ⅛-in. thick rubber gasket mat, which covers the inset metal bottom of the can. A sheet metal cup resting on the D.O. bottle frame holds the bacteriological sample bottle steady.

A heavy metal cap, made of a 2½-in. pipe cap machined, tapered, bronzed, and fitted with a swivel screw eye, is used to cover the neck of the sampler until the desired depth, as measured by a tag on the lifting rope, has been reached. An air release tube of about 8⅝-in. height above the lid and projecting 1¾ in. below the lid is brazed into the lid beyond the neck. The tube is 2⅛ in. off center, on the same diameter as the two neck orifices, and is a copper pipe of ½-in. internal diameter. A ⅝-in. diameter marble sphere (an ordinary boy's marble) is let into an enlargement of the air release tube at the 8-in. height and is prevented from escaping from the tube by a 1/16-in. brass cotter pin near the upper end. The marble constitutes the cutoff valve.

Three brass U bolts, securely fastened by nuts within the cylinder and brazed to prevent leakage through the cylinder wall, are used for attaching the lifting ropes, which are swivel-hooked and lead to a common ring made of 3/16-in. stock. Three wing nut, washered, galvanized iron bolts are fitted with swivel attachments to the container to clamp the lid in place. The sampler weighs 28 lb. empty. Hook snaps are used on all the rope sections for easy handling and cleaning of the apparatus.

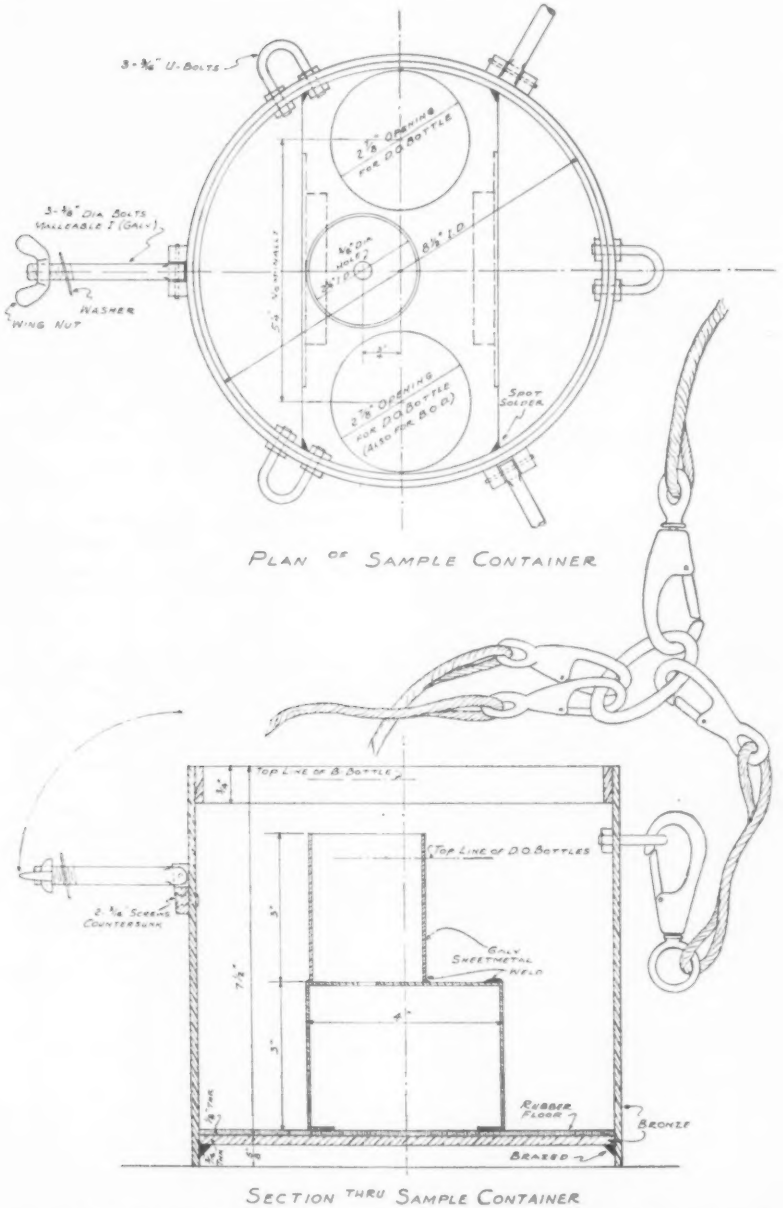

FIGURE 3.—Working drawing for construction of semi-automatic deep-water sampler.

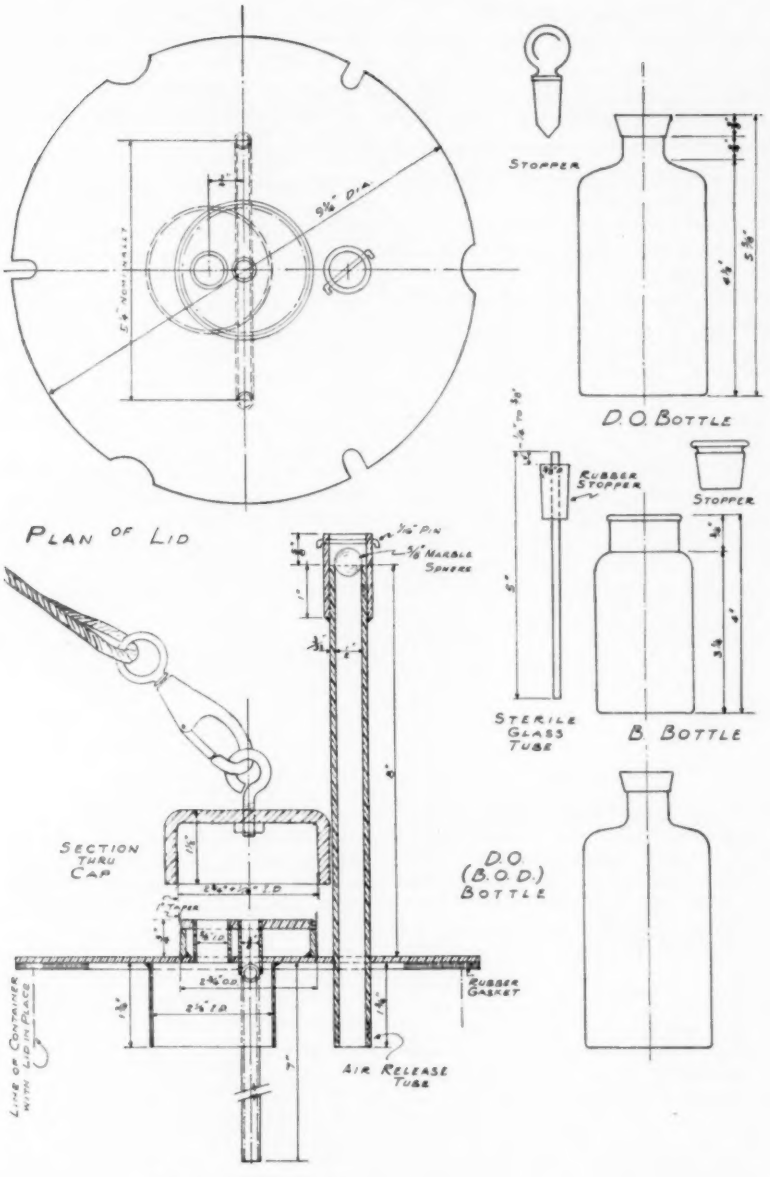

FIGURE 3—(Continued).

Operation of Sampler

With bottles in place, stoppered sterile tube inserted in its orifice, and lid clamped down tight, the metal cap is placed over the neck. The sampler is then lowered into the water being sampled. When a depth tag on the suspending line is just at the water level, the metal cap is removed by a sturdy tug on the cap rope. This permits immediate ingress of water through the neck orifices into the bacteriological bottle through the sterile tube and into the D.O. bottles through the copper tube manifold. Flowing water displaces the contained air in the sampler, the air under pressure bubbling up out of the air release tube. The operative head is the differential head between the marble sphere cutoff valve and the varying water level within the sampler. When water has risen within the sampler to the bottom of the air release tube—that is, to within 1¾ in. of the under side of the lid—the remaining air in the cylinder is trapped and compressed. Bubbling then stops, of course. The operator, seeing the cessation of the bubble stream, hauls the sampler up and opens it.

The filling thus described takes about 45 sec. at the 4-ft. depth. During this 45-sec. period of substitution of water for air within the sampler, several interchanges of water have occurred in the D.O. bottles at the given depth, but only one bottleful has entered the bacteriological sample bottle. As the sampler is drawn upward, following the cessation of bubbling, the marble valve at once drops back on its seat and the back pressure of the trapped air in the tightly sealed cylinder prevents further ingress of water. Consequently, a representative sample of reasonable integrity of the water at the depth of the entrance orifices has been obtained for laboratory analysis.

The positive action of the sampler has been repeatedly demonstrated on several stream pollution and water surveys, where it has given consistent results.

WATER POLLUTION IN THE UNITED STATES

Under the title "Water Pollution in the United States," the U. S. Public Health Service recently issued a report setting forth the first national summaries of data for initial state and federal studies on development of comprehensive pollution abatement programs for the nation's waterways.

Among the indicated needs are 10,000 new waste treatment plants, replacements, and additions or enlargements, which, together with installations necessary to keep up with industrial expansion and population growth over the next decade, will require public and private investments of $9,000,000,000 to $12,000,000,000. In addition, the needs of 1,600 municipalities and 5,500 industrial establishments are still undetermined. Despite the reduction of pollution by 9,300 treatment plants now operating, including 6,700 municipal and 2,600 industrial plants, wastes still discharged into rivers and lakes are equivalent to those from a population of more than 150,000,000.

The report gives some very interesting graphical analyses of municipal and industrial pollution sources; and treatment plant numbers, operation, and construction; all as of July 1, 1950. A tabular summary gives more comprehensive basic data on the status of pollution conditions in the major drainage basin areas of the country.

Copies of the report are available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at a cost of 35¢ each.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

MANHOLES ARE DEATHTRAPS

Manholes, so necessary in sewer systems and sewage treatment plants, are probably the most treacherous structures with which sewage works personnel have to deal. Here is truly the civilian counterpart of the infamous war-time "booby trap," whereby unthinking individuals are made to accomplish their own destruction through incautious action.

In the case of a manhole, however, no mechanical genius is needed to set the stage for tragedy—the trap is always set for the unwary. This point is well brought out in the report on a double tragedy published elsewhere in this "Corner." Certainly the surveyman who first entered the manhole in the case reported did not think of the possibility of an oxygen deficiency. It is also obvious that the would-be rescuer who followed him to his death gave no thought of it either. That further fatalities did not occur among the other three who so incautiously entered the same manhole in quick succession was only due to rapid ventilation of the confined space by natural means, not to any precaution on the part of those involved.

Oxygen deficiency—one of the most potent of killers—is not detectable by sight, smell, or feel. Nevertheless, its presence is real. Decomposing organic matter is not a necessary component, as pointed out by the fact that the manhole involved in the reported case was on a new sewer, to which sewage had not been admitted. Natural soil conditions surrounding the unventilated manhole structure were shown to be the cause of the oxygen depletion. Water standing in the manhole bottom and covering both the inlet and outlet pipes only contributed to the lack of air movement in the confined space; it did not remove oxygen from the manhole atmosphere.

Under the circumstances, even the most poorly informed worker should have been suspicious enough to take some precautions about entering the manhole. That four others should so rashly follow in rapid succession seems almost incredible, especially after the second man had been so quickly incapacitated. One can only attribute such foolhardiness to the instinctive reaction to help a fellow worker in distress, without concern for the consequences in the excitement of the moment.

One of the cardinal rules of safety for working in confined spaces is to be sure the place is well ventilated before anyone enters. To open a manhole and immediately enter, even with a safety belt and a husky partner standing by outside, is to take an unnecessary risk with the most precious possession a man has—his life.

H. P. O.

OXYGEN DEPLETION IN A SEWER MANHOLE

By G. J. Raschka and W. J. Uber

Associate Public Health Engineer, Division of Industrial Health, and Assistant Public Health Engineer, Division of Water Pollution Control, respectively, Section of Environmental Sanitation, Minnesota Department of Health, Minneapolis, Minn.

On Friday, October 13, 1950, a request was received from Winona, Minn., for analyses of two gas samples collected from the bottom of a 26-ft. deep manhole, in which two workmen had died. The samples reached the laboratory on Monday, October 16, and upon examination were found to contain 2.5 per cent carbon dioxide, 7 per cent oxygen, a possible trace of combustibles, no carbon monoxide, and 90.5 per cent nitrogen by difference. The cause of death, then, was obviously lack of oxygen or asphyxiation, as symptoms of anoxia begin to appear in an atmosphere containing less than 16 per cent oxygen at normal pressures and become increasingly pronounced with further decreased oxygen concentration. The reason for the reduced oxygen concentration was not so obvious, however, and was made the subject of the investigation reported herein.

Several of the events leading up to the accident appear to be important. The manhole in question, designated as number 9 in this report, was part of a new sewer system being constructed to serve a new housing development in Glen View Addition, located in the southwestern part of Winona on a rise overlooking Burns Valley Creek. Construction of the upper portion of the sewer system—manholes 9 through 20—terminated on August 22, 1950, with the completion of manhole 9. At the time of the accident, construction was under way on the line between the existing sewer on Highway 61 and the completed portion of the Glen View Addition system, with the sewer having been laid to manhole 8. Construction of the sewer system in this order resulted in the collection of ground water in the lower end of the section from manhole 9 through 20, because the connection to the existing sewer had not yet been made and, therefore, this section of sewer had no outlet.

On October 10 the project had progressed to the point where construction of the sewer line between manholes 8 and 9 was begun, and a crew of city workmen prepared to check the grade line between these manholes. Manhole 9 was opened and one man entered with a leveling rod. Part way down he looked up as if to say something and then fell from the ladder. A second crewman, apparently assuming the first man had either slipped or become ill, entered the manhole to assist him. The second man reached the bottom of the manhole, lifted the first from the water and called for a rope, then collapsed. A third, a fourth, and a fifth man went down in rescue attempts. A fireman wearing a gas mask also entered the manhole. The third and fourth men experienced physical distress and were unable to climb back out. However, by the time the fifth man entered the manhole the oxygen concentration had apparently increased to near normal, for he noticed no ill effects. Efforts to revive the first two men failed.

On October 13 the two gas samples submitted to the Minnesota Department of Health were collected from near the water surface in the manhole and the cover was locked in place pending further investigation.

On October 17 the writers met with municipal representatives to discuss the circumstances of the accident and to initiate a study of its cause.

Sanitary Survey

As previously outlined, construction of the system occurred in several steps.

TABLE I.—Test Boring Logs and Analyses, Glen View Addition, Winona, Minn.

Boring No.	Location	Upper Layer			Lower Layer		
		Depth (ft.)	Soil Type	Vol. Mat. (%)	Depth (ft.)	Soil Type	Vol. Mat. (%)
6	30 ft. E. of MH 7	0 to 4	Silty loam	—	4 to 8	Silt with clay	—
7	130 ft. W. of MH 8	0 to 11	Sandy silt	—	11 to 20	Fine sand[1]	—
8	MH 9	0 to 12	Silt and loam	3.36	12 to 26	Silt[2]	1.68
9	130 ft. S. of MH 9	0 to 8	Silty loam	4.4	8 to 12	Sandy silt	2.65
10	75 ft. N. of MH 10	0 to 4	Silty loam	6.85	4 to 8	Silty clay	8.38
11	125 ft. S. of MH 10	0 to 4	Silty loam	6.23	4 to 8	Silt with clay	6.05
12	65 ft. N. of MH 11	0 to 3.5	Silty loam	8.12	3.5 to 8	Silt	6.79
13	135 ft. S. of MH 11	0 to 3.5	Silty loam	8.15	3.5 to 8	Silt	5.84
14	60 ft. N. of MH 12	0 to 4	Silty loam	8.3	4 to 8	Silt with clay	6.18

[1] Water at 15 ft. [2] Water at 16 ft.

The lateral sewer system serving the houses in the addition was constructed first and included the sewer from manholes 12 to 20, and manholes 13 to 20. This phase was completed on July 18, 1950. Construction of the trunk sewer from manhole 12 to manhole 9 was started on July 20, 1950, and completed on August 22, manhole 9 being the last item of construction.

This section of the trunk sewer was laid in ground which had at one time been the bed of a mill pond formed by a dam on Burns Valley Creek. Results of test borings (see Table I) made prior to construction indicated that the subsoil was more or less uniform in nature. The principal soil type found was silt, with some silty loam, silty clay, and silt with sand occurring. Analyses of the boring samples showed a relatively high content of organic matter. The heavy deposition of silt in this area apparently resulted from the stilling effect of the mill pond.

Ground water was encountered in only two of the test borings. At test hole 8, which coincided with manhole 9, the record shows approximately 10 ft. of water above the invert elevation. At test hole 7, 170 ft. east of manhole 9, approximately 5 ft. of water was found. The water surface elevation of Burns Valley Creek at the time of the investigation appeared to be several feet below the invert of the trunk sewer.

The history of the construction of the trunk sewer from manhole 12 to manhole 9 indicates that wet ground was encountered, but that the greater part of the work progressed rapidly enough to prevent accumulation of appreciable amounts of water in the trench. However, at manhole 9 it was necessary to dewater during construction. The sewer was jacked under Highway 43, and contains two leaded joints and one mechanical joint.

Manhole 9 contained approximately 5 ft. of water on October 17. On October 30 the water depth had decreased to about 4 ft., where it stood at the time of dewatering. With this amount of water in the lowest part of the system, the inlets and outlets of manholes 10, 11, and 12 were completely submerged, effectively sealing each manhole and preventing ventilation along the sewer.

When this investigation was initiated, two houses in the addition were connected to the completed portion of the sewer but were not using the building waste systems. One of the houses had been occupied only the day before the accident and had no water supply. An inspection of the sewer manholes and the plumbing fixtures indicated that there had been no discharge of sewage from either house.

Test Procedure

An investigation was made on October 17 to substantiate the analyses of the gas samples previously submitted and also to determine the circumstances responsible for oxygen depletion. To obtain gas samples, a rubber hose was dropped through the 1-in. hole in the cover of each manhole and the samples withdrawn. They were analyzed for oxygen, carbon dioxide, carbon monoxide, hydrogen sulfide, and combustibles. A further depletion in oxygen was found in manhole 9, but the concentrations in manholes 10, 11, and 12 were only slightly less than normal (see Table II). After the gas samples were taken, the manholes were opened and samples of the water were collected for bacteriological, biological, and chemical analyses (see Tables III and IV).

The object of a return visit on October 19 was to attempt to duplicate the depletion of oxygen in manhole 9 under controlled conditions. Analysis of the atmosphere in manhole 9 showed conditions similar to those found on October 17. By ventilating, through use of sailcloth and a gasoline-driven blower, the oxygen concentration in this manhole was brought up to a normal atmospheric concentration of approximately 21 per cent. Another set of water samples was then taken to follow any change which might occur in the liquid in the manholes. After collection of gas and water samples the manholes were closed and a layer of earth placed upon the cover of each to minimize the effects of natural ventilation.

On October 25 the oxygen was again found to be depleted in manhole 9, but not appreciably in manholes 10, 11, and 12. The results of the analyses of water samples previously collected were now available, and calculations based on these results showed that the large oxygen depletion found during this test could not be attributed to the condition of the water in the manhole. A dredge was used in an attempt to collect any material on the bottom, but only construction debris was brought up. At this time it was decided, on the basis of analytical results, that conditions in manholes 10, 11, and 12 were stable. Therefore, no further sampling was done at those locations.

After consideration of evidence obtained thus far, it appeared likely that the oxygen in the manhole was being lost by diffusion into the ground or that the entire manhole atmosphere was being displaced by gaseous nitrogen from the ground. To substantiate this, on October 30 the manhole was aerated and inspected, the cover sealed with asphaltic material, and an attempt made to meter the movement of gas inward or outward. No flow of gas

TABLE II.—Analyses of Atmospheric Samples, Sewer System, Glen View Addition, Winona, Minn.

Date	Manhole 9		Manhole 10		Manhole 11		Manhole 12	
	CO_2(%)	O_2(%)	CO_2(%)	O_2(%)	CO_2(%)	O_2(%)	CO_2(%)	O_2(%)
10/13/50	2.5	7.0	—	—	—	—	—	—
10/17/50	2.8[1]	3.0[1]	0.3	19.5	0.1	19.5	0.1	21.0
10/19/50	3.0	4.0	0.5	21.0	0.5	21.0	0.5	20.5
	0.5[2]	21.0[2]	—	—	—	—	—	—
10/25/50	3.5[1]	3.0[1]	0.5	19.0	0.5	20.0	0.5	19.5
10/30/50	3.0	6.0	—	—	—	—	—	—
	0.1[2]	19.5[2]	—	—	—	—	—	—
11/6/50	2.0	12.0	—	—	—	—	—	—

[1] Some ventilation occurred when manhole was opened after sample was taken.
[2] After ventilating.

TABLE III.—Analyses of Water Samples, Sewer System, Glen View Addition, Winona, Minn.

Determination	Manhole No. 9			Manhole No. 10		Manhole No. 11		Manhole No. 12
	10/17	10/19	10/30	10/17	10/19	10/17	10/19	10/19
Bacteria (no./ml.)	25,000 21,000	5,200	—	8,500	360,000	—	300	6,100
Coliform organisms (M.P.N./100 ml.)	160,000 54,000	17,000	—	460	110	—	230	490
Total solids (p.p.m.)	660	670	620	—	780	—	—	650
Total vol. matter (p.p.m.)	250	130	240	—	280	—	—	170
Total hardness (p.p.m.)	230	220	—	430	420	430	490	290
Alkalinity (p.p.m.)	490	420	420	450	430	470	470	420
pH	9.4	7.6	7.7	7.8	7.6	7.5	7.4	7.2
Dissolved oxygen (p.p.m.)	0.0	0.0	—	0.0	0.0	—	0.0	0.0
Sulfates (p.p.m.)	33	31	—	—	48	14	13	37
Chlorides (p.p.m.)	9.0	8.5	—	—	8.5	7.0	9.0	11
Nitrate nitrogen (p.p.m.)	<0.01	<0.1	—	<0.03	<0.1	<0.01	<0.1	0.054
Nitrite nitrogen (p.p.m.)	0.0025	0.0030	—	0.0037	0.58	0.23	0.0016	0.0034
Ammonia nitrogen (p.p.m.)	6.1	5.8	—	1.0	0.42	2.0	1.5	1.6
Kjeldahl nitrogen (p.p.m.)	6.9	5.8	—	—	1.1	2.2	2.2	2.5
Organic nitrogen (p.p.m.)	0.8	0.0	—	—	0.70	0.2	0.7	0.9
5-day B.O.D. (p.p.m.)	33	22	15	24	9.3	1.0	11	1.8

could be detected. The manhole was then pumped out and a second inspection of the interior was made. The inspections showed a number of small areas of discontinuous plaster on the walls. The inlet and outlet had been sealed during construction with sheets of rubber inner-tubing wired onto the ends of these pipes to limit the flow of water into the manhole while work was in progress. It was observed that the inlet seal had ruptured, but sand and other construction debris had so obscured the outlet that it could not be found. After pumping had proceeded for some time, the pump discharge gave off a distinct sulfide odor, which had been absent at the beginning of the operation and which disappeared before dewatering was complete.

The metering and gas analysis results obtained on October 30 indicated that the rate of oxygen depletion had decreased to the point where little change was occurring. Another visit was made on November 6 to confirm those indications. Analysis of the atmosphere in the manhole showed only partial oxygen depletion.

Discussion

It was apparent from the results of the gas analyses that there was insufficient oxygen in manhole No. 9 to support life. (The results of mass spectrograph tests on duplicate samples confirmed the results of the gas analyses made in the field, and showed only the normal air constituents.) These results led to the conclusion that

TABLE IV.—Biological Analyses, Water in Manhole 9, Sewer System, Glen View Addition, Winona, Minn.

Organism	Number per Liter
Diatoms:	
Gyrosigma sp.[1]	363
Navicula sp.[1]	363
Protozoa:	
Holotrichida[2]	284,660
Total	285,386

[1] Probably from surface water source.
[2] Ciliate protozoa growing on organic matter and bacteria.

oxygen depletion alone was responsible for the accident.

The greater part of the field investigation, then, was devoted to an attempt to determine the reason or reasons for the oxygen depletion. Until the rate of depletion had been determined, it was felt that perhaps oxygen was being absorbed by the water in the manhole. This was shown not to be the case, however, by examination of the water. Bacteriological samples showed no significant pollution such as would have been the case if sewage had been present, although a considerably higher concentration of organisms was found in manhole No. 9. The five-day 20° C. B.O.D. (biochemical oxygen demand) was somewhat higher in manhole No. 9 than in the others, but the difference was not significant. Calculations indicated that the progressive decrease in B.O.D. in manhole No. 9 was in general accordance with values for a theoretical rate.

The rate of oxygen depletion in manholes 10, 11, and 12 was found to approximate the rate at which oxygen would be absorbed in these circumstances by water with little dissolved oxygen. This rate is determined by such factors as surface area, temperature, dissolved oxygen concentration, and oxygen solubility. Normally, the only manner in which the organic material in water—as measured by the B.O.D.—influences the rate of absorption is by reducing the dissolved oxygen concentration. When, as in the case of the present investigation, the dissolved oxygen concentration is very low, an increase in the B.O.D. has little effect on this rate.

The results of calculations made for the purpose of determining the rate at which oxygen could be absorbed from the air under conditions existing in the manholes showed that the depletion found in manholes 10, 11, and 12 could be attributed to absorption alone. This was not the case in manhole 9. There, the rapid rate of oxygen depletion, repeatedly demonstrated, was many times greater than could be accounted for by absorption into the water, regardless of organic material content. The results of the investigation also ruled out the possibility that the oxygen depletion resulted from some chemical, biological, or physical reaction occurring on the wall surface.

In view of the conclusions regarding absorption into the water in the manhole, it was evident that the oxygen depletion was due to either a dilution by soil-air, which would be predominantly nitrogen at this depth, or diffusion of the oxygen through the masonry wall into the surrounding soil, where it would be absorbed, or a combination of both. Soil aeration is primarily a diffusion process, which may be influenced by such factors as soil saturation, temperature, barometric pressure, and the nature of the soil. In the subsoil strata at this location, where the organic content of the earth is high, it is probable that the soil-air is partially or completely devoid of oxygen. The high oxygen demand of this organic matter would have the effect of accelerating the diffusion of oxygen through the masonry wall into the soil, where it would be completely absorbed by a biochemical oxidation process.

One of the major decomposition products formed by such a process occurring in the soil usually is carbon dioxide. The somewhat higher than normal concentration of this gas found in the manhole seems reasonable, because part of the carbon dioxide thus produced would diffuse back into the manhole, even though the gas would be quite soluble in the alkaline ground water.

Safety Aspects

A significant fact about the accident of October 10 is that water had accumulated in the manhole. The sealing of inlet and outlet pipes thus prevented natural ventilation of the sewer, permitting the accumulation of nitrogen and accompanying depletion of oxygen, which led directly to the accident. Un-

der different construction circumstances, work would have started at the lowest point on the sewer system and proceeded up-grade, providing for continuous drainage and ventilation of the completed portion of the sewer. This is customary construction practice and should be followed except where circumstances make it impossible.

As was shown at Winona, a new sewer system—one in which no sewage has flowed—is not necessarily a safe system to enter. This and other accidents of a similar nature emphasize the fact that closed manholes, wells, or other enclosures not subject to natural aeration constitute potential traps for those unaware of the hazards of entering such spaces. By taking the simple precaution of lowering a safety lamp into all such openings before entering, adequate warning will be given if the oxygen concentration is insufficient to support life or if explosive gases are present. If such is the case, the space should not be entered until further tests with the safety lamp show that the remedial measures, such as ventilation, have been effective in restoring normal air to the space, or unless a proper respiratory protective device is worn.

Conclusion

The results of this study show that the cause of death of the two workmen was lack of sufficient oxygen in the air in the manhole to maintain life. It is concluded that the oxygen concentration was reduced by diffusion into the surrounding soil, by dilution of the air in the manhole with air which upon passing through the surrounding soil had lost all or most of its oxygen, or by a combination of both processes.

THE DAILY LOG

Fort Wayne, Indiana

By Paul L. Brunner and L. L. Larson

Superintendent and Assistant Superintendent, respectively

May 15—The Fort Wayne sewage treatment plant is in its eleventh year of operation and "Old Man Corrosion" seems to have taken up permanent residence with us, as his efforts and antics are beginning to show up very definitely. This is not news to most operators, but in spite of a rather vigorous campaign of preventive maintenance it is necessary to begin a program of replacement. In addition to the usual "wear and tear" problems, there have been several breaks in pipelines due to ground settling, which can be expected because a large part of the grounds is composed of fill. These line breaks include: a 6-in. gas line from the digester to the engine, a 3-in. fill line for the fuel oil tanks, a 4-in. air line to the primary tanks, 3-in. underground sprinkling lines, and a number of electrical conduits. In the case of conduits, whenever possible, the line is re-routed inside the building and trenchlay cable is used in the ground.

May 25—We're right in the midst of our second run of cleaning 1,200 diffuser plates. The plates are 12 in. by 12 in. by 1 in., Alundite type, with an original porosity of 40 c.f.m. (± 10 per cent). The ones selected for cleaning were those in the first ⅔ of the inlet chamber of each tank, where the air passage had dropped to less than 10 c.f.m. They are immersed in a sulfuric acid-dichromate mixture for 48 hr., then soaked in city water for three days. Then they are rinsed clean in

a special header box, using a mixture of air and water. After drying for a week over our main air header the plates are tested for porosity grading. So far, the cleaning has resulted in an average improvement of more than 80 per cent.

June 3—The regular 18-month engine overhaul has been completed, including the usual routine of changing valves, inspection of bearings, new piston rings, crankshaft deflection measurements, and replacement of gaskets. It also included the installation of a new piston liner in the No. 3 cylinder. An annoying and persistent thump or knock was traced to No. 3 and finally diagnosed as being at the point where the liner fitted into the lower frame casting. An 0.008-in. oversize liner was used and did the trick, much to the satisfaction of all concerned, including the insurance inspector.

Piston rings have not been a serious headache for our gas engine, but in the current overhaul a new type of chromium plated compression ring was installed. The success of this experiment will not be known for some time and comment will be made later.

June 8—At the suggestion of the insurance inspector the four 125-hp., 3-speed, electric motors for the raw sewage pumps were serviced. They were disconnected and moved out to the blower room floor, where the rotors were removed, blown out with air, and washed with carbon tetrachloride. The insulation and connections were then checked, followed by two spray coats of black glyptol insulation varnish. About 2 weeks were required for each motor, with the moving, etc., being handled by a responsible rigger. Expenses were classed as preventive maintenance.

June 14—An experiment that went haywire. It was hoped that the life of screenings grinder blades could be increased if they were tipped with a well-known alloy. However, they proved to be too brittle and were broken by some of the hard materials sometimes present in our screenings.

June 17—The average life of the tubes in our engine exhaust gas heat exchanger has been approximately 18 months. After checking with Dave Backmeyer (Marion, Ind.) on his experience with brass tubes, we installed Chase antimonial tubes and hope they do as well as Dave's. The tubes are 1½ in. O.D., 13-gage, 63½ in. long, rolled into headers, handle 1,000° F. exhaust gases on the inside, and cool, soft water at 50-lb. pressure on the outside. We would be glad to trade experiences with anyone interested.

July 1—The digester slopes seemed to be a favorite breeding ground for buckhorn, dandelions, and various other weeds. Through the cooperation of the Board of Works, a good dosing of 2,4–D was applied. The weeds have been discouraged; in fact, they have been completely eliminated and the grass cutting is more pleasant.

Foaming has occurred in the aeration tanks at odd intervals, but not as severely as at some plants. We have been able to control the foaming by sprinkling a small amount of used oil on it. We're not Scotch, but we had to dispose of the oil anyway.

The sewage plant has been assigned the only large-capacity bulldozer in the city utilities; for 10 years we have been struggling along with a 1933 model, which finally ran its nose into the ground and gave up the ghost. Now, we have a nice, new orange 2-cycle, 48-hp., diesel tractor equipped with an 8-ft. blade and a 1-cu. yd. front-end loader. It is a very versatile and useful piece of equipment and we expect it will pay for itself in due time if we can keep it on the premises. Our experience has been that other departments also find new uses for such equipment.

July 6—We have noticed a definite decrease in the fly population the last two years without any city-wide DDT program. Is this a general situation or is it just local?

Noting that the Navy approves of

nylon flags, we went out on a limb and purchased two. We now have the finest flags in town and by careful cleaning we hope that the extra life and service will justify the purchase.

For some time we have noticed a loss of gas from our Hortonsphere, which was charged up to leaky diaphragm control valves, safety pop valves, etc. However, we located the leak in the ½-in. underground line leading to the recording pressure and volume gage on our control board. It also happened that this line comes into the building near our transformer yard, which had become badly infested and undermined with rats. As the leak became noticeable, the rats disappeared. It was decided that this was an expensive way to eliminate rats and the line was repaired. We were able to obtain enough ¼-in. copper tubing to replace the galvanized pipe and feel that we have a more satisfactory replacement and with considerably less expense.

July 9—Another piece of new equipment that we appreciate and are proud of is a sandblasting machine, which we use to remove scale and old paint from pipework in aeration tanks, and from scraper arms, steelwork in the final tanks, etc. Everyone knows what a tedious job it is to do this by hand and the blaster (Figure 1) speeds this work up tremendously and also does a much better job. Our standard underwater painting program schedule includes a good cleaning followed by two coats of Bitumastic No. 50.

Did you ever come to work in the morning and find the screenings grinders plugged up with catfish? One of our park lagoons, which is used as a bluegill hatchery, was recently seined and drained out, and in some way the catfish, which were from 3 to 6 in. long got into the sewer. They sure mess up a grinder. We have encountered only one thing worse—a particular type of waste from wire enamel

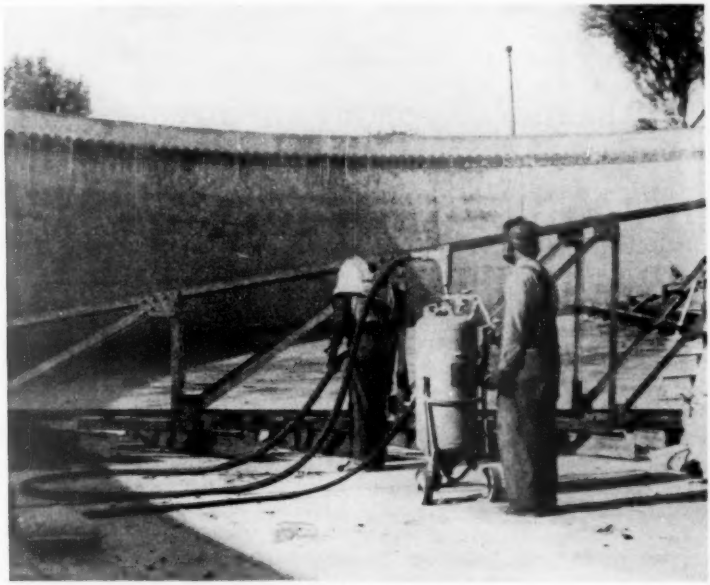

FIGURE 1.—Portable sandblasting machine speeds job of removing scale and old paint from steelwork in preparation for repainting.

plants, which seems to congeal best just as it hits our grinders.

July 11—There are about 450 plug valves in this plant and about 100 other places that require greasing. A rather elaborate greasing schedule has been worked out and one man has been assigned this work, which requires about one-half of his time. We soon found that we had acquired so many varieties of grease that it took a magician to keep them straight. We are now using a "multipurpose" grease, which is proving quite satisfactory, and we are very gradually replacing the other types. It is hoped that eventually we will have reduced our inventory to 2 or possibly 3 greases, which we believe is good business.

July 14—A maintenance inspection of our aeration building heater reminds us that the original plans for the aeration building provided an office for the operator, but no provision was made for heating the building. The first effort at heating was an oil stove, which made the office, at least, comfortable. Because of the moist conditions of air in this building, the windows frosted up badly in winter and at other times the condensation on the metal sash and doors was very heavy. As a result severe corrosion set in. To help this condition, the next improvement was the installation of a home-type gas furnace in the basement of the building. One hot-air duct was run to the office and the other two hot-air outlets were fitted with dampers and discharged into the open basement. Warm air comes upstairs by means of the two stairways and numerous open gratings. A 1-in. gas line with a suitable flame trap, etc., was run from the main boiler room through the tunnel to the furnace. With 8-in. water pressure on the gas, the gas consumption in cold weather averages 2,000 cu. ft. per day. The net result of this installation is: cheap fuel, warm comfortable building, dry basement, very few frosty windows, and a definite reduction of corrosion of the doors and window frames.

CLEANING OF POROUS AIR DIFFUSERS *

By A. Bruce and R. J. Stephenson

Northern Outfall Sewage Works, London County Council, London, England

In activated sludge plants using diffused air, the maintenance of air diffusers in the best possible condition is of major importance. It is generally agreed that the clogging of the porous diffuser medium is brought about by a number of factors, which vary according to local conditions. As a result, many methods of dealing with the widespread problem of cleaning diffuser media, which have been employed successfully both in Great Britain and in the United States, may not give satisfactory results in some localities. A review of the subject by Wisely (1), based on comments and data furnished from 25 activated sludge plants, gives some indication of the wide range of service periods after which media have to be reconditioned. Some of these periods are as long as 15 years. In some instances, however, clogging has led to such difficulties that open-ended pipes or perforated tubes have been substituted for diffusers.

Wirts (2)(3) has given costs of cleaning diffuser plates. As in the authors' experience, the labor cost involved in removing and replacing plates accounts for the greater part of the expenditure. A cleaning method which

* Presented at a recent meeting of the Metropolitan and Southern Branch, Institute of Sewage Purification, England.

would enable the permeability of the plates to be restored without removing them from their holders would, therefore, have great advantages. More recently (4), flame cleaning of the surface of clogged diffuser plates with a high-temperature oxyacetylene flame was stated to have been used successfully at the New York City plants.

Rust Largely Responsible

At the London County Council's Northern Outfall works the greater part of the air compressed is used in reactivating the spent sludge from the settling tanks of the activated sludge plant (5). This process is carried out in 25 reaeration channels, 24 of which each contain 195 to 205 cast-iron trays, into each of which six alundum plates (8 in. by 6 in. by ¾ in.) are fixed by means of brass screws and wax washers. The remaining channel contains 120 trays of the same type. These diffuser trays, which are 4.5 ft. long and have a central air inlet, are laid in the furrows of the 290-ft. channels. Investigation of the state of the upper and lower surface of the plates and consideration of the local conditions led to the conclusion that clogging was brought about by the following causes:

1. Activated sludge solids being forced into the plates when the air pressure in the supply pipes falls or is interrupted.
2. Iron rust on the underside of the pores of the plates from the rusting of the air supply pipes.
3. Hard-water scale.
4. Gelatinous growth of organisms on the top surface.
5. Grease accumulation on the top of the plates.
6. Coal dust and soot from the atmosphere.

Apart from the clogging of the diffuser plates, considerable trouble is also experienced from the accumulation of the rust deposit in the bottoms of the trays and the partial blocking of the small control valves and downpipes by rust scales. This excessive rusting probably is caused by the condensation of water from the warm compressed air throughout the entire system under certain weather conditions. Experiments are in progress in which plastic tubing is being used in place of the 1-in. galvanized wrought-iron downpipes.

Previous Procedure

Of the several generally known methods of cleaning tried at the Northern Outfall works, the most satisfactory had, in the past, been found to be the burning of the plates at 900° C., although the process did not quite restore the original permeability of the plates. The labor charge involved in removing the plates from their holders was very high and many plates and screws were broken, owing to the difficulty of the operation. In addition, new wax washers and rubber joints for the plate seats were required when the reconditioned plates were replaced in the holders. It was also necessary to re-rate the plates so that all the plates in any one tray would have a similar degree of permeability. Owing to the time required by this tedious and expensive operation, the diffusion of air into the plant steadily deteriorated and the air pressure in the system rose from 6.5 to 8 lb. per sq. in. Even so, insufficient air was passed to effect a reasonable reconditioning of the activated sludge. It became imperative, therefore, to develop a method whereby the tiles could be cleaned without their removal from the trays.

The presence of wax washers precludes any treatment involving the use of heat. A cleaning fluid must be able to dissolve or remove organic material, including grease, as well as iron oxide and carbonate, and hard-water scale. A solution of sodium dichromate in sulfuric acid, which has been used by Schade and Wirts (2) and other workers, would, during the long periods of treatment advocated, attack the metallic parts and the rubber and wax washers. In view of the large amounts of

rust scale in the holder tray, the process would also prove expensive to use. In the course of the laboratory investigation, certain combinations of chemicals were tried, as it was thought that it might be possible first to remove organic substances, including grease, with one agent, and the rust and hard-water scale with diluted hydrochloric acid with its action on metals inhibited, if necessary, by the addition of glue to the solution. Hydrogen peroxide, in strengths up to 100 volumes, was used with but a small measure of success for the first operation. It was found, fortunately, that 30 to 50 per cent (weight/weight) caustic soda could be used on the surface of the dry plates without detriment to the wax washers, brass screws, rubber washers, and cast-iron trays. Furthermore, when treatment of the plate was continued with commercial hydrochloric acid diluted with an equal volume of water, the permeability was almost completely restored. Both sodium hydroxide and hydrochloric acid have often been used by other workers, but it would appear that the effect of their use in sequence has not been tried in these concentrations.

Plate Cleaning Procedure

The method finally developed for cleaning the plates in the plant was as follows:

1. The trays were brushed and hosed down, disconnected from their air supply pipes and removed from the reaeration channel. They were then laid out in rows, face upwards, on an asphalt surface and scrubbed and washed to remove as much dirt as possible with deck brushes.

2. The plates were allowed to dry partially and an application of 30 per cent caustic soda was made and spread with a rubber brush on the exposed face of the plate. Penetration took place slowly. A second application was made 1 hr. later, and allowed to stand overnight. It is desirable that trays should be protected from rain and strong winds, which cause the sodium hydroxide to be converted to carbonate before penetration has been effected.

3. The trays were then washed with a hose and at this stage as much loose scale as possible was shaken out and washed from the inside of the trays. The trays were then placed side by side on a long, carefully levelled trestle, and each tray was connected to the water supply by means of a short piece of rubber tubing and a cork so that a gentle trickle of water passed through each plate. The washing was continued until the surface of the plates gave no reaction to litmus paper. When the process of cleaning was made a continuous operation, the washing was carried out for a definite period (not less than 4 hr.) with occasional checks with litmus paper. The trays were then emptied by turning them over and the water in the plates was blown out with compressed air.

4. A mixture of one part commercial hydrochloric acid and one part water, containing a very small quantity of Teepol, was poured in by means of the air connection until the tray had been filled, and then left for 1 hr. Normally, 0.5 gal. of diluted acid was used for each tray. Where considerable effervescence took place, time was allowed for it to subside before completing the addition of the acid. (In cases where a large amount of deposit is present inside the tray it may prove advantageous to carry out the acid treatment in two stages so as to be sure that the end tiles have been treated adequately.)

5. The trays were then washed by connecting the water supply to the air inlet until the water coming through the plates had no yellow color (about 1 hr.). Any remaining scale which had been loosened was also shaken out and the water remaining in the plates was blown out with air.

6. Each tray was tested for uniformity and permeability by placing in a trough of water and connecting to a reduced air supply and a water gage.

Emphasis is laid upon the necessity for washing the plates free from alkali after the caustic soda treatment. It might be thought that so soluble a substance as caustic soda would be readily washed out. Experiments showed that alkali could remain in the plates not only after an hour of washing, but also even after an hour of treatment with the acid. It was found that the plates could always be freed from caustic soda by prolonged washing, without removing them from their holder trays.

It is essential that the operators carrying out the process should be provided with protective clothing, rubber gloves, and goggles. It was not found necessary to use glue as an inhibitor in the acid solution. The use of wetting agents in conjunction with the caustic soda solution did not speed up penetration to any appreciable extent, but addition of Teepol (0.5 oz. to 10 gal. of diluted acid) showed appreciable advantage.

Testing

The permeability of a dry diffuser plate has little relation to the permeability of the same plate when wet. Therefore, as Setter and Edwards (6) have suggested, it would be advisable to make permeability tests with the plates wet instead of dry, as in practice the plates are always covered with water. When testing a dry plate in the usual manner it is not possible to observe the uniformity of diffusion over the entire surface of the plate, whereas any irregularity is readily observed when the plate is under water. The dry permeability test is more sensitive than the wet test, but this is no advantage in practice. It is occasionally found that a plate which has been cleaned by burning passes an abnormally large amount of air through a localized area of the surface and little through the remaining area, although giving a normal dry permeability rating. New tiles which had become clogged in service and which had then been cleaned by chemicals were generally found to give remarkably uniform diffusion over the entire surface. As their original positions in the holder tray had not been changed, the necessity for matching was eliminated.

The best method of testing the trays is considered to be the observation of their behavior when submerged under 1 in. of water, a water manometer reading being taken of the pressure required in the actual plant operation. Each tray in the Northern Outfall plant is called upon to pass approximately 3 c.f.m. of free air; that is, 0.5 c.f.m. for each plate or 1.5 c.f.m. per sq. ft. A tray of six plates is rejected if the pressure shown on the gage is more than 7 in.; that is, 6 in. of water pressure loss in the plates when passing 3 c.f.m. of air.

Compressed air from the supply at about 7 p.s.i. is admitted through a pressure relief device to a low-pressure bellows-type meter. The entrance valve is adjusted until the specified rate of 3 c.f.m. is obtained and the actual pressure in the tray is read, in inches, on a water gage. Adjustment of the valve is not required often, as with an air supply at a pressure equivalent to a head of about 18 ft. of water, the variation in the pressure loss in the diffuser plates is relatively small. In practice, considerable variation in the volume of air is required to cause small changes in the pressure in the tray, but since it is the rise of pressure in the diffuser system which ultimately demands, for economic reasons, that the diffusing media be cleaned, this method is considered to be the most useful.

Most of the readings obtained were in the following pressure ranges: new trays, 4.8 to 5.4 in.; trays chemically cleaned, 5 to 5.6 in.; trays with plates cleaned by burning, 4.2 to 5.8 in.; each tray containing six plates.

The effect of cleaning the plates on the amount of dissolved oxygen present in the mixed liquor in the channels has also been studied by using the

sulfamic acid modification of the Winkler method. When working with activated sludge it is desirable to add the sulfamic acid reagent as soon as possible after the sample has been taken.

When a sludge containing no dissolved oxygen or only a trace was entering a channel it was found that the oxygen content would usually be increased to about 50 per cent saturation during its 16-hr. passage along a channel in which were used either new plates or those chemically cleaned. A comparison of the channels in this way (Table I) indicated that the chemically cleaned plates were working effectively. The sampling positions, 1 through 7, were spaced equally along the length of the channel, position 1 being near the inlet weir.

The cost of cleaning diffuser trays by using chemicals is much lower than the cost of cleaning the plates by burning, mainly because the time and materials required are so much less. The average time required per channel for chemical treatment is 10 days, whereas 6 weeks are required when the diffuser plates are fired. Furthermore, the only materials required for cleaning are the chemicals themselves, whereas the materials required in firing the plates involve new rubber joints, wax washers, and brass securing screws. Comparative costs of cleaning the plates of a channel by both methods are given in Table II.

TABLE I.—Comparison of Effectiveness of Chemically Cleaned and New Plates in Reaeration Channel

Sampling Position[1]	Dissolved Oxygen in Reaeration Channel			
	Chemically Cleaned Plates		New Plates	
	(p.p.m.)	(% sat.)	(p.p.m.)	(% sat.)
Inlet	Trace	Trace	Nil	Nil
1	1.1	11	1.0	10
2	1.8	19	2.3	24
3	3.0	32	4.2	45
4	4.3	45	5.0	53
5	5.1	53	5.4	57
6	5.0	52	5.4	57
7	5.0	52	5.1	54

[1] Sludge reaeration channel.

TABLE II.—Comparative Costs for Cleaning Plates of One Reaeration Channel

Item	Cost ($)[1]	
	Chem. Method	Burning
NaOH, 150 lb.	6.61	—
HCl, 50 gal.	10.50	—
Materials	—	246.26
Firing	—	147.00
Labor	211.69	562.59
Total	228.80	955.85

[1] Figured at £ = $2.80.

No allowance has been made in Table II for replacement costs caused by breakages, etc. In the chemical cleaning process replacements due to breakages were negligible. In the firing process, however, where the plates are removed from the trays, the breakage of plates was some 8 to 10 per cent; during dismantling some 6 to 8 per cent of the cast-iron trays themselves were broken. Further, it was found that many plates were seriously warped following the firing process, resulting in many breakages during replacement of the plates. Some plates were so badly warped as to require discarding on sight.

Conclusions

1. Chemical cleaning is practicable for standard flat diffuser plates in general use in the British Isles.

2. Diffusers can be cleaned without removing rubber or wax washers or screws.

3. No injury is suffered by the iron trays as a result of exposure to acid.

4. In the case of plates not previously treated by firing, treatment with caustic soda and then with hydrochloric acid gives uniform porosity and so avoids the necessity of matching to insure even distribution over the whole face of each diffuser.

5. The work can be carried out, in

large measure, without specially trained labor.

6. The time during which a unit is out of service is reduced, when chemical cleaning is used, to about one-quarter of that normally needed.

7. The chemicals required are cheap and easily obtainable, and the over-all costs are little more than one-quarter the costs of dismantling, furnace cleaning, transport, and re-assembly.

8. Chemical cleaning was put into operation on a large scale in the early part of 1949 and channels cleaned then are still giving good diffusion, which compares closely with that given by channels put into service at the same time with plates reconditioned by firing. Records indicate that plates which have been satisfactorily cleaned by the new chemical method will give good service for at least a year. With new plates a longer service (more than two years) can be expected in some cases. There is reason to believe that where the chemical cleaning method has been used on plates not previously reconditioned by firing, a longer effective life, which will compare more closely with that given by brand new plates, will be obtained.

Acknowledgments

Grateful acknowledgments are made to Dr. A. Daley, Medical Officer of Health, and J. Rawlinson, chief engineer, London County Council, for affording the facilities for carrying out this work. Also to C. J. Regan, chief chemist, and W. P. Warlaw, divisional engineer, Main Drainage Division, L.C.C., and to G. S. Clements and colleagues at the Northern Outfall works for useful help and criticism.

Thanks are also expressed to A. F. Green for making the sound film of the cleaning process to accompany presentation of the paper.

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TIPS AND QUIPS

Aluminum is Drafted

If you are wondering why the Government has cut back the use of aluminum for civilian goods, take a look at a few of the many military uses for this metal: 3.5-in. rocket-launching super bazooka; rockets and other rocket-launching equipment; G. I. helmets; aircraft landing mats; tactical and floating bridges; radar equipment and towers; walkie talkies; fire control towers; portable shelters; mess kits; construction equipment, such as bulldozers; "invasion pipe" for fuel lines; piping and shipping containers for handling rocket fuel chemicals; PT boats, submarines, amphibious vehicles, and all kinds of ships; unloading ramps and related assault equipment; water and fuel tanks; foil for radar reflection and for packaging food and metal parts; field kitchen equipment; firearms; engine parts for tanks, trucks, and other vehicles; medical field chests;

and numerous other applications, many of which are classified. Some 50 tons of aluminum are used in each Air Force B–36 bomber.

In addition, large quantities of aluminum powder, normally used in making aluminum paint, are now being shipped to manufacturers of explosives. Blockbusters, naval torpedoes, incendiary bombs, and star shells are only a few uses of this important powder.

All this is after the aluminum has been extracted from its ore. However, there is at least one important—to the average person, that is—interference with the extraction process itself. Cryolite, a mineral solvent used in the electrolytic production of aluminum, also is used as an insecticide in warding off hornworms from certain types of tobacco. With tobacco the strategic material it is, surely no one would dream of diverting cryolite from the tobacco fields to aluminum plants!

FIGURE 1.—Combination hand truck and stacker will handle 500-lb. load to 54-in. height.

Dual-Purpose Hand Truck

A new type of hand truck with built-in hydraulic hoist for lifting and stacking has been introduced. This combination hand truck and stacker (Figure 1) is used for loading and unloading heavy cases, drums, and barrels from ground level where loading docks are not available. Of compact sturdy construction and weighing only 111 lb., it has a capacity of 500 lb. and will lift these loads to tail-gate height of 54 in. The platform, 22 in. by 19 in. for accommodating large-size packages, has its front flush with the floor when lowered. The rubber wheels are of 8-in. diameter. The hand lift stacker is produced by Clark-Hopkins Equipment Corp., Philadelphia, Pa.

Sauce Source

Among the interesting little items that cross our desk from time to time is the following comment by Paul Brunner, superintendent of the Fort Wayne, Ind., sewage treatment plant:

"October is the time of the year when our grounds furnish fall shaggy-mane mushrooms, not only for the employees, but also for the neighbors. There seem to be three schools of thought on the reasons for the good crops. The first claims that sludge promotes the mushroom growth; the second, that grit is better. The third group remains unconvinced, as the tidbits also are found where neither sludge nor grit has ever been present."

Personally, we've always felt that mushrooms were best found where there was an underlying base of tender, thick, juicy steak!

New Non-Seize Thread Compound

Seizure of pipe, bolt, and stud threads and gasket faces has presented an obstinate problem. A new metallic anti-seize compound, Led-Plate, is claimed to combine the advantages of a lubricant and sealer to solve this problem with effective results when used in temperatures from − 350° to + 900° F. The materials will not dry out, according to the manufacturers, thereby assuring later disassembly against seizure. No graphite is used. The compound, said to be useable for steam, gas, water, air, oil, ammonia, and various chemical connections, was developed by Armite Laboratories, 6643 Broad Street, Los Angeles 1, Calif.

Medal of Honor for Helping Hands

Considerable interest has been aroused in some quarters by the publicity given in this "Corner" to involuntary membership organizations in the sewage works field. Latest to come to our attention is contained in a letter from Robert E. Leaver, secretary of the Pacific Northwest Sewage Works Association, who writes:

"Those in the sewage works field in the Pacific Northwest have been greatly interested in the Illinois organization, S.O.W.H.E.S.S., as described in the Operator's Corner (THIS JOURNAL, **23**, 2, 249; Feb., 1951), and in the South African system (THIS JOURNAL, **22** 10, 1371; Oct., 1950). However, we in the states of Washington, Oregon, and Idaho have a still different system, which we feel is more select and involves greater honor, there having been only two recipients to date—Oliver Johnson, Pullman, Wash., and Norman Waggoner, Seattle, Wash.

"To be awarded the Sewage Medal of Honor, it is necessary that the recipient get his hands or feet dirty while pulling out a man or woman (double credit allowed for clusters) from immersion in sewage or sludge. These medals are very much sought after. In fact, one man was disqualified recently because he pushed another in and then rescued him. This subterfuge is not allowed under present rules.

"A typical situation would read as follows:

'This Sewage Medal of Honor is accorded to.....for his valiant rescue of a sewage saturated (man or woman) from a.....tank on the .....day of.....19... Mr..... did, with no regard for the cleanliness of his own hands or feet, extend them to a fellow man in distress and thereby shortened the period of immersion in (sewage or sludge) by.....full minutes.'

"We will put the hands or feet of our recipients at time of action up against any and all comers!"

Safety Stickups

Safety signs on extra-strength cotton cloth with a self-adhesive backing are the latest wrinkle for marking potential danger spots in and around the plant. The message is shown in large bold letters on the proper safety code background color and each sign is coated with silicone plastic to protect it from dirt, grime, moisture, and weather. They are claimed to be usable for either indoor or outdoor application. No screws, bolts, etc., are needed to put them up, as they stick without moistening to any clean surface. The safety signs, which conform to National Safety Council standards, were developed by W. H. Brady Company, Chippewa Falls, Wis.

Iron and Steel Scrap Needed

At the request of the National Production Authority, local chambers of commerce and trade associations throughout the country are organizing Scrap Mobilization Committees to carry out programs for keeping high-grade scrap moving into steel mills and foundries. The drive is designed to lo-

cate on a nationwide scale the types of high-grade scrap that have not been flowing freely into normal channels of trade. NPA points out that much of the increased tonnage of steel scheduled for the defense program and civilian needs must come from industry in the form of dormant scrap.

Although the usual spring cleanup has probably long since been completed at most sewage treatment plants, there no doubt is quite a little scrap lying about that could be serving some useful purpose if it got to the right place—which is your local scrap dealer.

Emergency Planning

With materials and equipment priorities getting tighter all the time, Donald E. Henn, manager of the DeKalb (Ill.) Sanitary District, is making sure that his local industrial "information service" is functioning at top notch. This is in anticipation of possibly needing outside aid in the event of a major breakdown when emergency repairs or equipment replacements are hard to come by or are delayed in delivery.

The "service" is simple, but in the few instances when it has been needed it has proved remarkably effective. Essentially, what it amounts to is having as plant electrical repairman a local expert who is called on for the same service by most of the industries of the city. With his knowledge of the motors and other electrical equipment of so many industrial plants, he is in an excellent position to know just where equipment of the types needed by the sewage treatment plant can be found, as well as whether or not it can be borrowed for emergency use.

"Double Take" Department

Visitors to the office of Superintendent R. W. Frazier, Oshkosh, Wis., for a long time had been keenly aware of a badly out-of-plumb stack clearly visible on a near-by industrial plant. The usual reaction was a violent Hollywood type "double take," followed by the inevitable question: "Is that chimney out of line or am I cockeyed?" So many times was the question asked that a sign was placed in the window reading: "No, you're not cockeyed—the chimney is."

The stack was recently torn down and replaced by a new steel one, truly perpendicular. This, however, started the question again—until the sign was removed!

Reviews and Abstracts*

Effect of Temperature and Presence of Hypochlorite on the Rate of Hydrolysis of Cyanogen Chloride in Alkaline Solution. By G. E. Eden and A. B. Wheatland. *Jour.*, Soc. of Chem. Indus., **69**, 166 (1950).

This paper reports in detail some of the work conducted by the Water Pollution Research Board in Great Britain in 1948, and is based on the observation that cyanogen chloride is formed as the first reaction product of a cyanide with a hypochlorite. The mechanism is described to be the formation of cyanogen chloride followed by hydrolysis with the possible formation of cyanate. Inasmuch as cyanogen chloride is of somewhat the same order of toxicity as the original cyanide, and under certain conditions would remain unhydrolyzed in the receiving stream, it was desirable that information be developed on the rate of hydrolysis of cyanogen chloride under some of these conditions. The rate of formation of cyanogen chloride is rapid, but hydrolysis proceeds more slowly and is dependent on such variables as time, temperature, pH value, and concentration of excess hypochlorite.

In another report covering the work of the Water Pollution Research Board ["Destruction of Cyanide in Waste Water by Chlorination," Eden, G. E., *et al.*, *Jour.*, Soc. of Chem. Indus., **69**, 244 (1950)] it was concluded that a pH value of 11 was the most suitable for the reaction between cyanide and hypochlorite. Accordingly, the rate of hydrolysis of cyanogen chloride was determined at temperatures ranging from 0° to 30° C. in solutions buffered at a pH value of 11. It was concluded that at a constant pH value hydrolysis of cyanogen chloride was a reaction of the first order.

Another series of measurements was made on the rate of hydrolysis of cyanogen chloride in the presence of excess hypochlorite. Determinations were made at 0°, 10°, and 20° C. in the presence of hypochlorite in concentrations up to the equivalent of 27 p.p.m. available chlorine. It was found that at a constant pH value hydrolysis was again a first-order reaction, but that its rate was greatly accelerated by excess hypochlorite. Increase in rate was approximately proportional to the concentration of available chlorine. No hypochlorite was absorbed, however, during hydrolysis of the cyanogen chloride, and the authors offer a possible explanation that the apparent catalytic effect of the excess hypochlorite may lie in the formation of an addition compound with the cyanogen chloride which hydrolyzes with liberation of the original hypochlorite.

D. Milne

Annual Report of the Commissioner of Public Works, City of Fitchburg, Mass., 1949.

This report contains a section on the sewage disposal plant by W. Lamothe, operator. The estimated population served in 1949 is 43,000, with a sewage flow of 3.53 m.g.d., as compared with a water consumption of 6.7 m.g.d. The plant consists of Imhoff tanks, trickling filters, secondary tanks, with sludge drying beds. A summary of the data follows:

	Basis	
	Design	1949
Imhoff tanks, detention (hr.)	3	6.33
Per capita flow (g.p.d.)	125	81.8
Trickling filters:		
Area (acres)	2.12	—
Area in use (acres)	—	1.86
Load per acre (m.g.)	2.0	1.89

The average number of nozzles cleaned per day was 10.2. The volume of sludge (both Imhoff and secondary) was 917,000 gal. per year. Skimmings from Imhoff

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and education institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

tanks averaged 3.3 cu. ft. per day. Flow of sewage through the Imhoff tanks was reversed at least once a month. Sludge beds were cleaned twice in 1949. No analytical data are given.

LANGDON PEARSE

Annual Report 1948–49, Institute for Sewage Treatment (Netherlands). By C. P. Mom. 60 pp.

Organic wastes usually can be treated biologically, but wastes containing large quantities of inorganic salts should be discharged in or close to the sea. The tendency in some industrial centers is to seek a solution in that direction. It has been suggested to build outfalls to salt water for large volumes of industrial wastes and treating domestic wastes locally. Since the last war, oil fields have been developed, the wastes of which threaten to present difficult problems.

A survey of 40 tanneries showed that the volume of waste varied from 265 to 530 gal. per cowhide, with a population equivalent of 20 to 40. Sludge production by settling amounts to 4 to 7 per cent of the volume of waste.

Extensive stream pollution studies were made, indicating that many of the smaller streams are highly polluted.

Surveys made on the basis of complaints that cattle contracted tuberculosis by grazing in meadows through which run ditches receiving raw sanatoria wastes showed the presence of alcohol-acid fast bacteria, which microscopically and in growth characteristics resembled tubercle bacilli. Six months after the sanatorium was closed no T.B. bacilli were found. Another survey of ditch water receiving the septic tank effluent from a sanatorium showed the presence of T.B. bacilli. In the neighborhood of another sanatorium, where it was suspected that cattle were infected with tuberculoses from drinking ditch water, the effluent from a sanatorium septic tank showed virulant T.B. bacilli. Tests of sewages from six large sanatoria showed many cultures of alcohol-acid fast organisms, among which were many saprophytes. In several cases, positive cultures of tubercle bacilli were obtained. The conclusions reached are: "In several cases positive cultures of tubercle bacilli were obtained, so that sewage from sanatoria indeed should be considered as possible infection sources for man and animals. Since man and cow are sensitive to each other's type of tuberculoses (respectively caused by human and bovine tubercle bacilli), interchange between human and bovine tuberculosis is possible, through direct or indirect contact; for example, through infected water. Sewage from sanatoria, communities, and wastes from dairies, are undoubtedly sources of tuberculosis infection."

During the year 25 new treatment plants were under construction (11 completed at the end of 1949) at a cost of 8,000,000 guilders. The number of sewage and waste treatment plants in Holland are:

Municipal	44
Barracks and military camps	13
Sanatoria and hospitals	9
Industrial	13
Slaughterhouses	8
Plans under way	128

Irrigation systems treating wastes from potato starch manufacturing are not included.

W. RUDOLFS

Water in Industry. National Assn. of Manufacturers and the Conservation Foundation, New York, N. Y. 51 pp. (1950).

Text, graphs, and tables of this booklet are crammed with factual results of a joint project survey made during 1950 by the NAM Committee on Conservation of Renewable Natural Resources and the Conservation Foundation covering water use practices of more than 3,000 industrial plants. Data are given on sources and quantity of water used, types of use and treatment, methods of disposal and degree of local pollution, and summaries by regions and metropolitan areas. The 3,343 completed questionnaires summarized came from plants producing 21 classes of products and representing all geographical areas of the country.

Of the 2,693 plants furnishing information on the degree to which intake of water is re-used, 61.3 per cent made no re-use, 9.4 per cent re-used up to 10 per cent, 4.8 per cent re-used between 10 and 19 per cent, 10.9 per cent re-used between 20 and 49 per cent, 6.6 per cent re-used between 50 and 99 per cent, and 7.1 per cent re-used more than 100 per cent. Waste water (2,904 plants) is not treated

before disposal by 82 per cent, whereas moderate treatment is provided by 12.6 per cent and essentially complete treatment by 5.3 per cent. Although no substantial number of plants in any one size group (number of employees) indicated essentially complete treatment of waste water, 44 per cent of the plants with more than 2,500 employees did provide at least some treatment, as compared with only 13 per cent of the plants employing less than 100. Of the 521 plants treating their waste water, 30 per cent reported recovery of useful by-products from it.

Of considerable interest are summary tables, by areas, of the industrial respondents' opinions as to the status and trend of water pollution in their own metropolitan and regional areas; and a preliminary tabulation of data on water use per unit of product in the various industries.

Copies of this informative bulletin are available without charge on request from the Conservation Foundation, 30 E. 40th St., New York 16, N.Y.

H. P. ORLAND

Report to Pennsylvania Sanitary Water Board on Clarion River Pollution Abatement. BY CAMP, DRESSER, AND MCKEE. 196 pp., 26 tables, and 34 figures (Mar., 1949).

The Clarion River watershed covers about 1,240 sq. mi., empties into the Allegheny River about 50 mi. northeast of Pittsburgh, and at the time of the report was grossly polluted by industrial wastes and domestic sewage.

It was found necessary to (1) define appropriate uses of the river, (2) establish water quality standards commensurate with these uses, (3) determine the stream's self-purification capacity, and (4) determine the quantity of polluting materials entering the stream.

The major portion of the pollution was organic in nature, with a population equivalent of 438,800, and was derived from municipalities, paper industries, tanneries, leather manufacturing, breweries, ink pigment manufacturing, and alum manufacturing. Thorough stream sampling was completed and rates of deoxygenation and reaeration were computed for various sections of the river. Example calculations of this painstaking work are given and should prove very helpful to others making similar surveys. A dissolved oxygen level in the river of 4 p.p.m. was the main objective of corrective measures.

A complete survey was made of each industry and municipality to determine the extent and properties of organic material contributed to the river. Recommendations for process changes, segregation of wastes, good housekeeping practices, and methods of treatment were made by the engineers. This often involved pilot plant studies, extensive sampling, and laboratory work. After this work was completed, recommendations were made for types of treatment and results to be attained by each industry or municipality so that pollution would be prevented.

The engineers recommended that the Commonwealth establish continuous dissolved oxygen recorders at strategic river points and that studies be made to develop continuous B.O.D. recorders so that continuous river quality could be recorded and steps taken to improve it in case quality becomes inferior to minimum standards.

The whole report is a very fine example of a rather complete river survey which illustrates the principle of "reasonable use" of an important natural resource, surface water.

K. W. COSENS

The California Water Plan. BY WILLIAM L. BERRY. *Jour.*, Amer. Water Wks. Assn., **42**, 4, 381 (Apr., 1950).

The surface and ground water situation today in California and the long-range means of allocating the existing water resources to meet the needs of the future, are described in this paper. Planning in the past on a state level has already prevented a water shortage in critical areas. The situation has been accentuated by the existence of heavy population, and industrial and agricultural concentrations in the southern and central portions of the state, whereas the major water resources are in the northern part.

In 1947 the California legislature appropriated funds recommended by the State Water Resources Board for the present program of statewide water investigations by the State Engineer. These investigations have as their objective the preparation of a plan for the full conservation, control, and utilization of California's

water resources, both surface and underground, to meet present and future water needs for all beneficial purposes and uses in all areas of the state, insofar as practicable. The plan to be based on this survey has been designated the "California Water Plan."

It is interesting to note that an inventory on the quantity and quality of sewage effluents and industrial waste water from major sources is being included for water resources in the state. The plan not only involves the conservation and utilization of water resources, but also the control of floods.

In order to preserve the water resources of the state, the 1949 legislature passed a comprehensive water pollution control program. The state has thus recognized the need of water pollution control in order to properly plan an effective over-all state water plan. Much of the work on the California Water Plan has already been accomplished and water resources inventories in the state indicate that they will be able to meet the probable ultimate requirements.

ROBERT P. LOWE

Economic Waste Disposal Problems in the Reconstruction of Our Cities. BY F. POPEL. *Proc.*, Abwassertechnischen Verein. (German), I, 67 (1949).

This paper deals with the preparation of a good quality, marketable fertilizer from sewage solids and garbage. The composted mixture of digested sewage solids and ground garbage yields a fertilizer comparable to farm manure.

The fresh solids are pumped to a primary digester. After the first-stage digestion the solids are elutriated in the lower chamber of a two-story wash tank, from which they pass to a secondary digester. The digested solids are then elutriated again in the top chamber before being pumped to drying beds or vacuum filters. For a population over 100,000 the use of the latter is more economical. Some of the ashes and dust from the garbage are used as absorbants for the drying beds. The solids thus produced have a high fertilizer value and the digestion gases have a heating value of 500 to 7,000 cal. per cu. m.

The garbage is composed of 33 per cent finely divided matter, 27 per cent medium size refuse (mostly organic matter), 36 per cent large size garbage, 19 per cent moisture, and 4 per cent scrap materials or trash (scrap iron and other metals, rags, glass, and paper). The garbage is sifted to separate the refuse dust. From the remainder, the trash is separated by handpicking from conveyor belts, the scrap iron being picked up by a magnet, dissolved in HCl, and used as a coagulating agent in the sewage treatment process. The remaining garbage is thoroughly mixed with the dried digested sewage solids in a ratio such that the organic material contains 25 to 30 times as much carbon as nitrogen.

This mixture is then composted in piles 1 to 6 m. high and 1 to 3 m. wide. Provision must be made for air access to the centers of the larger piles. The temperature of the manure heaps is kept between 45° and 50° C. by turning them over periodically for four months, when the composting may be considered completed. The fertilizer is then sifted on drum sieves to 12-mm. size. The residue is returned as seed to the incoming garbage.

PETER MUELLER

The Production of Compost from Sewage and Garbage. BY H. STRAUB. *Proc.*, Abwassertechnischen Verein. (German) I, 94 (1949).

At the experimental plant at Baden-Baden fresh sewage solids were thoroughly mixed with garbage, from which the larger materials (tin cans, glass, etc.) had been removed. The mixture was stacked in piles 3 by 3 by 100 m. provided with longitudinal air supply shafts and vertical air outlet shafts about 18 m. apart.

To obtain the best compost (containing 35 to 40 per cent moisture) the fresh solids, of 75 per cent moisture content, are mixed with the garbage in a ratio of 1:4 by weight, respectively. The process of decomposition takes 5 to 6 months, during which time the heaps should be turned over. The composting produces no odors; H_2S odors indicate improper composting because of air deficiency. To maintain manufacture of a uniform product, the additional ashes in garbage during the winter should be stored and added to the summer garbage. The final product is sifted down to 25 mm. size, leaving a 15 per cent residue, which can be ground and added as seed to the incoming garbage.

The fertilizer value of the compost is shown to be equal to or better than manure, and better than artificial dry fertilizer, especially for peas, potatoes, carrots, cabbage, etc. Besides the minerals, it provides much needed humus and minute quantities of the trace elements necessary for the health of plant, animal, and man.

A balance sheet shows that the product can be marketed more cheaply than any other fertilizer.

PETER MUELLER

Flow Currents in Rectangular Sedimentation Basins. By J. GEIGER. *Proc.*, Abwassertechnischen Verein. (German), I, 128 (1949).

The flow was observed in model tanks having one glass side and simulating modern sedimentation basins. The actual detention period was determined by measuring the concentration of an added dye colorimetrically in the influent and effluent at constant corresponding time intervals. With known inlet systems it was found that the liquid was not rapidly enough distributed over the entire cross section of the basin. An inlet system was devised whereby the liquid enters the basin at one end by means of inclined T-end pipes arranged so that the openings of horizontally adjacent pipes face each other. Complete distribution over the cross section of the tank was achieved in a distance equal to half the depth of the water. A 95.9 per cent detention efficiency (actual detention period over theoretical detention period) is claimed. The system is applicable to circular sedimentation basins.

PETER MUELLER

Further Experiences with the Roundworm Plague. By F. REINHOLD. *Proc.*, Abwassertechnischen Verein. (German), I, 146 (1949).

The roundworm problem in Darmstadt and surroundings (Germany) is discussed. The incidence of roundworm infection in 1947–48 in the Darmstadt-Griesheim area was 89 per cent out of 394 people examined. Roundworm infection is caused by the use of untreated or improperly treated sewage as fertilizer for vegetables. In 1947, 5,000 to 6,000 worm eggs per liter were present in the Darmstadt sewage.

Abatement and prevention can be achieved by:

1. Systematic medical treatment of infected people. Already a decrease from 700 eggs per c.c. in sewage sludge in 1947 to 70 eggs per c.c. has been noted.
2. Installation of properly working mechanical sedimentation tanks with 1- to 2-hr. detention period. An experiment is cited to show that all worm eggs can be removed from the sewage in settling tanks with 1-hr. detention period.
3. Disposal of fresh solids by anaerobic digestion followed by composting or dewatering on drying beds.

PETER MUELLER

Experiments on Oxygenation of Water and Sewage by Rotating Brushes. By A. PASVEER. Rep. No. 2, Comm. on Sewage Treatment (Netherlands). 25 pp. (1950).

The oxygenation of water in a tank equipped with rotary brushes takes place in the close vicinity of the brushes and especially in the mass of foam thrown up. It follows that oxygenation can be carried out just as efficiently and more economically in a small tank or channel as it can in large tanks. Experiments show that the quantity of oxygen per kilowatt-hour introduced into the water in a small tank is 8 to 10 per cent higher than in a tank of normal dimension. This effect is attributed to increased turbulence. The effect can be further intensified by placing a baffle in the path of the water leaving the brush to force the mass of foam to change direction, which results in a 25 per cent increase of oxygen taken up by the water.

H. HEUKELEKIAN

Book Reviews

The Analytical Balance—Its Care and Use. By W. M. MacNevin. Handbook Publishers, Inc., Sandusky, Ohio (1950). 73 pp. Price, $1.50.

This monograph provides practical information about the care and use of the modern analytical balance. It is designed to acquaint the average scientific worker with the problems of selecting, mounting, cleaning, adjusting, testing, and repairing a balance. It is also intended for the technical worker who has had little or no training in the use of the balance.

For the more advanced scientific worker the section on testing for performance characteristics will aid in obtaining improved performance from the balance. Special emphasis is placed on having major repairs made by a specialist in this field, but of being able to determine when repairs are necessary.

Noteworthy features of the monograph are a list of names and addresses of balance manufacturers and a list of names and addresses of balance repair specialists.

The Engineering Method. By J. C. L. Fish. Stanford University Press, Stanford, Calif. (1950). 186 pp. Price, $3.00.

Organized in this special volume from material originally presented as three chapters in a comprehensive treatise on the engineering profession, this book formulates for students the system of logic and reasoning that is the mark of the practicing engineer. By means of simple problems the author illustrates the steps of the method in logical sequence from the statement of the question to the ultimate choice of one of several alternatives. The final section deals with inescapable uncertainties in engineering work and the variety of ways in which the engineer copes with them.

Not only is the book an excellent text for students, but it also will provide the practicing engineer and administrator with a concise formulation of what he is and has been doing in making choices by—the engineering method.

Engineering Hydraulics. By Hunter Rouse *et al.* John Wiley & Sons, Inc., New York, N. Y. (1950). 1039 pp. Price, $15.00.

This compendium of 13 sections prepared by Professor Rouse, Director of the Iowa Institute of Hydraulic Research, Iowa State University, and 12 other authorities on various phases of engineering hydraulics makes a textbook of outstanding character. The several chapters were presented by the writers at the Fourth Hydraulics Conference at the Iowa Institute.

The book stresses principles more than it does practice. Each section, in the form of a monograph on the particular aspect covered, is complete in itself, although skillful editing has woven the entire work into an integrated book.

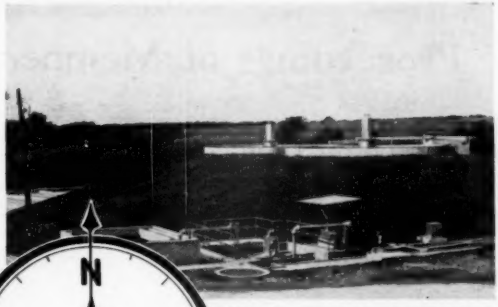
Of particular interest to sanitary engineers are the chapters on flow measurement, hydrology, flow of ground water, steady flow in pipes and conduits, channel transitions and controls, sediment transportation, and hydraulic machinery.

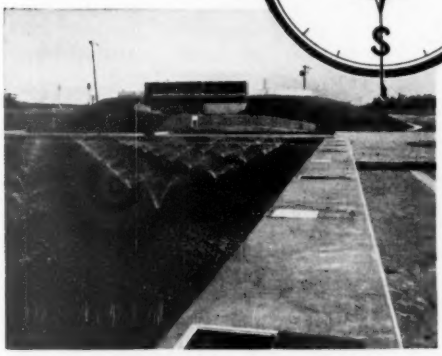
Civil Engineering Handbook. By Leonard C. Urquhart, editor. McGraw-Hill Book Co., New York 18, N. Y. Third Edition (1950). Price, $8.50.

Although still hardly pocket size, the new edition of this well-known reference work is of somewhat more handy dimensions than most handbooks. Presentation of the mass of data coming under the broad coverage of the title has been ably handled in terse cogent sections. The sections dealing with general hydraulics and sewage and industrial wastes are of reference interest to those engaged in these fields. It is in matters not specifically in these fields, however, that the book will be found most useful to the specialist, particularly in reference to basic theory, standards, practice, and data on such subjects as mechanics of materials, steel design, cement and concrete, framed structures, and foundations.

H. P. Orland

SEDALIA MISSOURI GOES MODERN





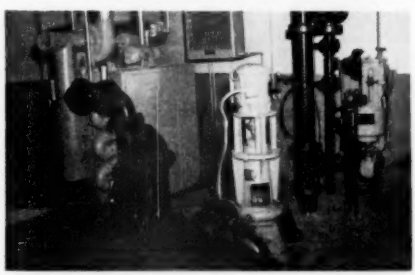
The three waste treatment plants at Sedalia, Missouri—the North, West and South Plants—have been completely modernized, utilizing all existing structures and equipment where economies in construction could be effective.

NORTH PLANT P.F.T. Controlled Digestion System with 2 - 30' floating covered digesters and #170 digester heater is included in this plant which utilizes the existing Imhoff tank as a secondary clarifier, also providing a new trickling filter to supplement the old P.F.T. fixed nozzle unit.

WEST PLANT The P.F.T. Controlled Digestion System at this plant was developed by modernizing two existing unheated digesters with scraper mechanisms with two P.F.T. floating cover digesters and supplying heat with a P.F.T. #170 heater. The existing P.F.T. fixed nozzle filter and final clarifier were used without change.

SOUTH PLANT A completely new P.F.T. Controlled Digestion System with a 35' P.F.T. floating cover and #100 digester heater replaces the old septic tank at this plant. The old contact filters were converted to sludge beds.

All three plants now embody the ultimate in modern "P.F.T. Controlled Digestion" systems including P.F.T. floating covers, P.F.T. supernatant selectors, P.F.T. digester heaters and P.F.T. gas safety equipment. All three digester heaters are also arranged to automatically supply the building heating requirements.



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P.F.T.

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Proceedings of Member Associations

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

The 22nd Annual Convention of the North Dakota Water and Sewage Works Conference was held at the World War Memorial Building, Bismarck, N. Dak., October 4–6, 1950. Registration for the meeting totaled 115.

An excellent opportunity for informal exchange was afforded on October 4, preceding the convention proper, when an open house was held at the Bismarck city shops, followed by a late evening Dutch lunch at the water treatment plant. Also included in the pre-convention activity was an inspection trip to the Madan, N. Dak., sanitary landfill operation.

The meeting was welcomed on the morning of October 5 by Mayor Kleppe of Bismarck. The remainder of the session was devoted to Conference business.

In the afternoon, papers were presented as follows:

"Iron Removal," by Verne Luther, Layne-Minnesota Co., Minneapolis, Minn.

"Municipal Financing," by Myron H. Atkinson, city auditor, Bismarck.

"Cathodic Protection," by Willard H. Bell, Wallace and Tiernan Co., Inc., Minneapolis, Minn.

"Missouri River Basin Program," by K. S. Krause, sanitary engineer, Missouri River Basin Office, U.S.P.H.S., Kansas City, Mo.

"Municipal Legal Responsibility," by A. O. Goplen, assistant State Attorney General, Bismarck.

"State Water Pollution Control Program," by W. Van Heuvelen, director, State Water Pollution Control Board, Bismarck.

At the Annual Banquet, held the evening of October 5, R. W. Hart, regional engineer, U.S.P.H.S., Kansas City, Mo., spoke on "Biological Warfare."

The morning session on October 6 opened with a paper on "Civilian Defense," by R. O. Saxvik, North Dakota State Health Officer. This was followed by concurrent group discussions for sewage works and waterworks operators led by A. E. Williamson, Bismarck, and George J. Toman, Mandan, respectively.

Following the Annual Business Luncheon, an inspection tour was made to the Riverdale water treatment plant and Garrison Dam.

Officers elected for 1950–51 were:

President: H. H. Behler, Fargo.
Vice-President: K. R. Johnson, Dickinson.
Secretary-Treasurer: J. H. Svore, Bismarck.

JEROME H. SVORE,
Secretary-Treasurer

LOUISIANA CONFERENCE ON WATER SUPPLY AND SEWERAGE

The 1951 Annual Meeting of the Louisiana Conference on Water Supply and Sewerage was held at Louisiana State University, Baton Rouge, March 28–30, 1951, in conjunction with the 14th Annual Short Course for water and sewage personnel. Sewage personnel numbered 22 of the total registration of 101.

Besides the usual short course discussions and forums, the sewage works sessions featured the following papers:

"Civil Defense," by John H. O'Neill, Louisiana State Board of Health.

"Public Relations," by C. F. Con-

(*Continued on page 226a*)

New Orleans' famed Cabildo and Cathedral of St. Louis in the Vieux Carrê as seen 100 years ago

New Orleans has a cast iron gas main in service that was installed well over a hundred years ago. Vehicular traffic in those times was a far cry from today's giant buses and trailer trucks. The engineering term—*traffic shock*—was then unheard of. There were no sewers, conduits and other underground services to cause soil disturbance. Yet this old cast iron main has had the shock-strength, beam-strength and effective resistance to corrosion to withstand the changes and unforeseen stresses of more than a century. New Orleans' experience is not exceptional. Cast iron water and gas mains, laid over a century ago, are still serving in the streets of more than 30 cities in the United States and Canada.

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NUMBER SIX OF A SERIES

tois, Gulf States Utilities, Baton Rouge.

Officers elected for the ensuing year were:

Chairman: N. Lorio, Marrero.
Vice-Chairman: L. J. Dore, Lafayette.
Secretary-Treasurer: G. H. West, Lake Charles.

S. V. HAZLIP,
Secretary-Treasurer

NEW JERSEY SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 36th Annual Meeting of the New Jersey Sewage and Industrial Wastes Association was held at the Haddon Hall, Atlantic City, N. J., March 14–16, 1951. This was the first meeting held outside of Trenton, a change which required an amendment of the Association's constitution. Registration totaled 306.

The always popular "Speechless" Dinner and Entertainment, sponsored by the Water and Sewage Works Manufacturers Association, again lived up to its well-deserved reputation as a highlight of the meeting.

Papers presented at the technical sessions included:

"An Example of Cooperation Between Industry and a Municipal Sewage Treatment Plant," by L. W. Steiger, chemical engineer, Maywood Chemical Works, and H. Van Der Vliet, superintendent, sewage treatment plant, Maywood.

"The Problem of Handling Small Sewage Flows," by L. J. Nemecsek, R. B. Carter Company.

"External Heating of Digesters," by Paul J. Cerny, The Dorr Company.

"Breaking in a New Sewage Treatment Plant," by Calvin Ellis, superintendent of public works, Moorestown.

"Comminutors," by J. P. Messina and R. Griswold, Worthington Pump and Machinery Corp.

"Twenty Years of Training Sewage Plant Operators," by B. I. Corson, instructor, Camden County Vocational School.

"Industrial Wastes, A Wormseye View," by L. L. Hedgepeth, technical consultant, Calco Division, American Cyanimid Corp.

"Camden's Intercepting Sewer and Sewage Treatment Program," by C. A. Emerson, consulting engineer, New York City.

"New Jersey Sewage Treatment Plant Operators in the State Public Health Program," by R. Shaw, acting chief engineer, Bureau of Public Health Engineering, State Department of Health.

"Air Pollution Abatement Today," by D. J. Cestoni, waste disposal engineer, Merck and Co., Rahway.

"The Raritan Valley Trunk Sewer System," by G. F. Smith, chairman, Middlesex County Sewerage Authority.

In addition, films were shown as follows:

"Construction of Worcester, Mass., Sewage Treatment Plant," by John L. Hayden, consulting engineer, Boston, Mass.

"Air, Water and Industry," by Dow Chemical Company.

"River at Your Door—Story of the Raritan," by Middlesex County Sewerage Authority.

A report on Federation activities was presented by Earnest Boyce, vice-president, FSIWA.

The final morning of the meeting was opened with an Operators' Breakfast and Business Meeting, followed by the Operators' Symposium, in which the following subjects were discussed:

"Licensing Law," by A. Leahey, public health engineer, State Department of Health.

"Labor Relations," by P. W. Hardy, councilman, Borough of Fair Lawn.

"Procurement of Supplies and Materials," by M. S. Kachorsky, borough engineer, Manville.

Officers held over from the previous

(*Continued on page 228a*)

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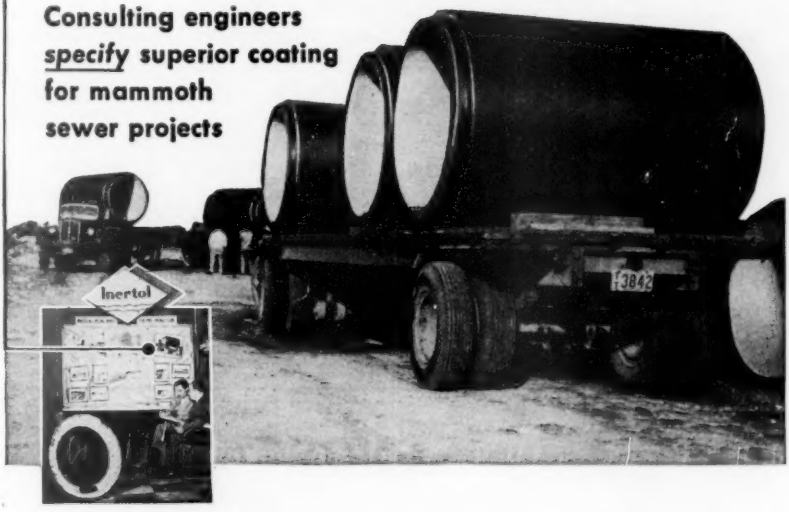

• At the recent New Jersey Sewage & Industrial Wastes Convention in Atlantic City, Inertol Co., Inc., pictorially reported the acceptance and overwhelming customer satisfaction in the use of Inertol #66 Special Heavy in giant sewer projects throughout the country. By displaying an impressive assortment of "in-use" photos, the company amplified the recognized superiority of this quality product.

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year (elected for two years) were:

President: John Struss, Wildwood.

1st Vice-President: Sol Seid, New Brunswick.

2nd Vice-President: Paul Molitor, Jr., Rutherford.

New officers chosen at the business meeting were:

FSIWA Director: Henry Van Der Vliet, Maywood.

Secretary-Treasurer: M. S. Kachorsky, Manville.

M. S. KACHORSKY,
Secretary-Treasurer

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The 1950 Fall Conference of the Arizona Sewage and Water Works Association was held November 30–December 2, at the Pioneer Hotel, Tucson, Ariz. Registration totaled 194 members and guests. A "No Host" dinner was held the evening of November 30 at the La Jolla Club.

Following a welcoming address by Mayor J. O. Nieman, the opening session on December 1 heard the following papers:

"Purchasing Material," by H. P. La Fortune, Manager of Purchases and Stores, Sacramento (Calif.) Municipal Utility District.

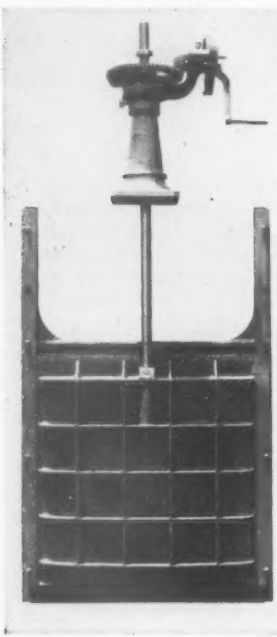
"Cement Joints, Their Cost, Experience, and Acceptance," by M. T. Bramman, District Sales Manager, James B. Clow & Sons, Los Angeles, Calif.

At the luncheon, Mrs. Lois J. Schulze, Membership Secretary, AWWA, was the featured speaker.

A panel discussion dealing with the public relations of a utility was given at the afternoon session. The panel was led by G. E. Arnold, Director, San Diego (Calif.) Water Department.

The speaker at the Annual Banquet was A. E. Berry, Vice-President of

(*Continued on page 230a*)



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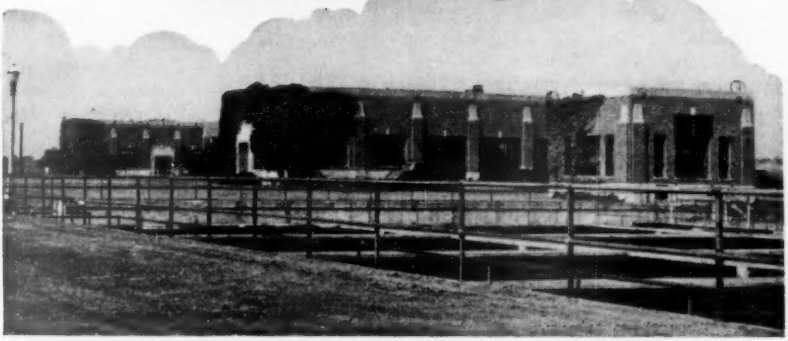

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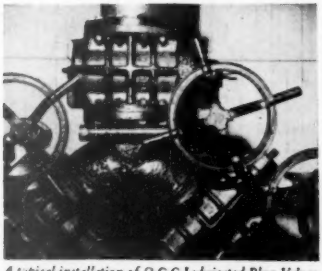

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AWWA, who discussed the activities of AWWA during 1950.

The technical session on December 2 opened with a film, presented by the Los Angeles Department of Water and Power, showing mobile equipment in sewer maintenance. Also seen were films from Tempe and Mesa, Ariz., showing recent water extensions and additions. These were followed by a paper on "Plumbing Cross Connections," by Charles Trygg, Sanitary Engineer, Arizona State Department of Health.

Following the Annual Business Luncheon, a panel discussion on the maintenance and operation of equipment, presided over by H. Arthur Price, Los Angeles Department of Water and Power, covered the subjects of maintenance of sewer and water equipment, use of mobile telephone equipment in operation of an irrigation district, sand traps, pump lubrication, and the importance of consumer metering.

The Conference concluded with a very enjoyable Dinner-Dance.

MRS. HELEN ROTTHAUS,
Secretary

OKLAHOMA WATER, SEWAGE AND INDUSTRIAL WASTE CONFERENCE

The 1950 Annual Meeting of the Oklahoma Water, Sewage and Industrial Waste Conference was held November 27 to December 1, 1950, at Oklahoma A. & M. College, Stillwater, Okla., in conjunction with the 24th Water, Sewage and Industrial Wastes Short Course. The near-record attendance of 154 included many new members, indicative of the continuing spread of interest.

Lectures, panel discussions, and laboratory sessions comprised the bulk of the technical program. Topics covered in the sewage works courses ranged from basic subjects to discussions of the problems involved in the most complex of sewage treatment installations.

Of interest to all were the following talks:

"Civil Defense and the Atomic Bomb," by Harold J. Karsten, Oklahoma State Department of Health.

"The Oklahoma Ground Water Law," by Clarence Burch, chairman, Oklahoma Planning and Resources Board.

"What is New in Sewage Works," by Ralph E. Fuhrman, president, FSIWA.

A new Industrial Wastes Section, organized within the Conference at this meeting, held special technical sessions during the last two days of the meeting. Papers presented at these sessions included:

"Industrial Wastes in Oklahoma," by Fred G. Fellows, consulting engineer, Ponca City.

"Chemistry of Corrosion," by O. M. Smith, Oklahoma A. & M. College.

"Salt Water Disposal," by Paul DeLozier, manager, Treat-Rite Chemical Co., Nowata.

"Industrial Wastes at Air Force Installation," by Charles Moore, chief of utilities, Tinker Air Force Base, Oklahoma City.

An extremely interesting new phase of the meeting consisted of a course for water and sewage works men in "How to Supervise." Conducted by M. L. Powers, executive director, Engineering and Industrial Extension, Oklahoma A. & M. College, the course encompassed 25 hours of discussion of the basic principles necessary for effective supervision.

Officers elected at the Annual Meeting and Banquet to serve during 1951 were:

President: R. B. Riddle, Frederick.
Vice-President: F. S. Lytle, Hominy.
Secretary-Treasurer: H. J. Darcey, Oklahoma City.

H. J. DARCEY,
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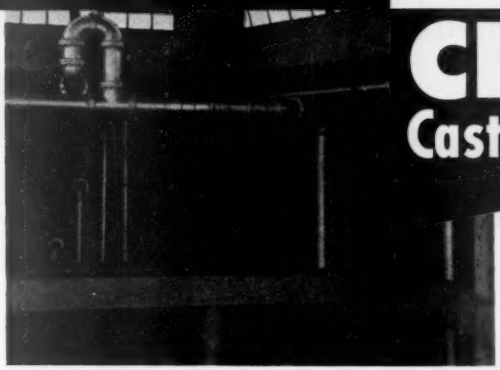

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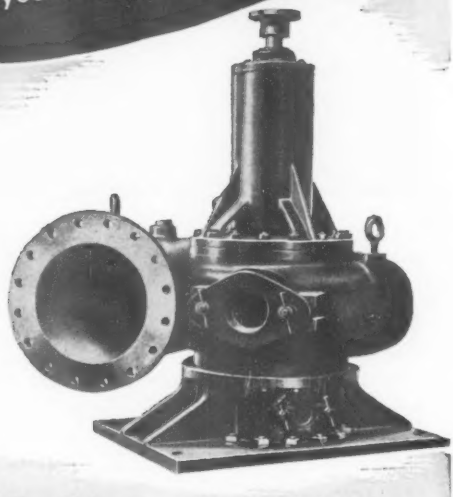

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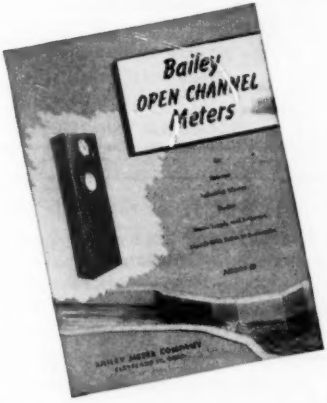

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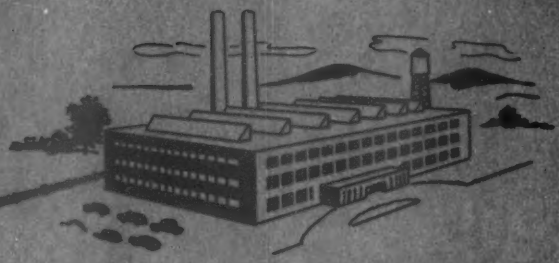

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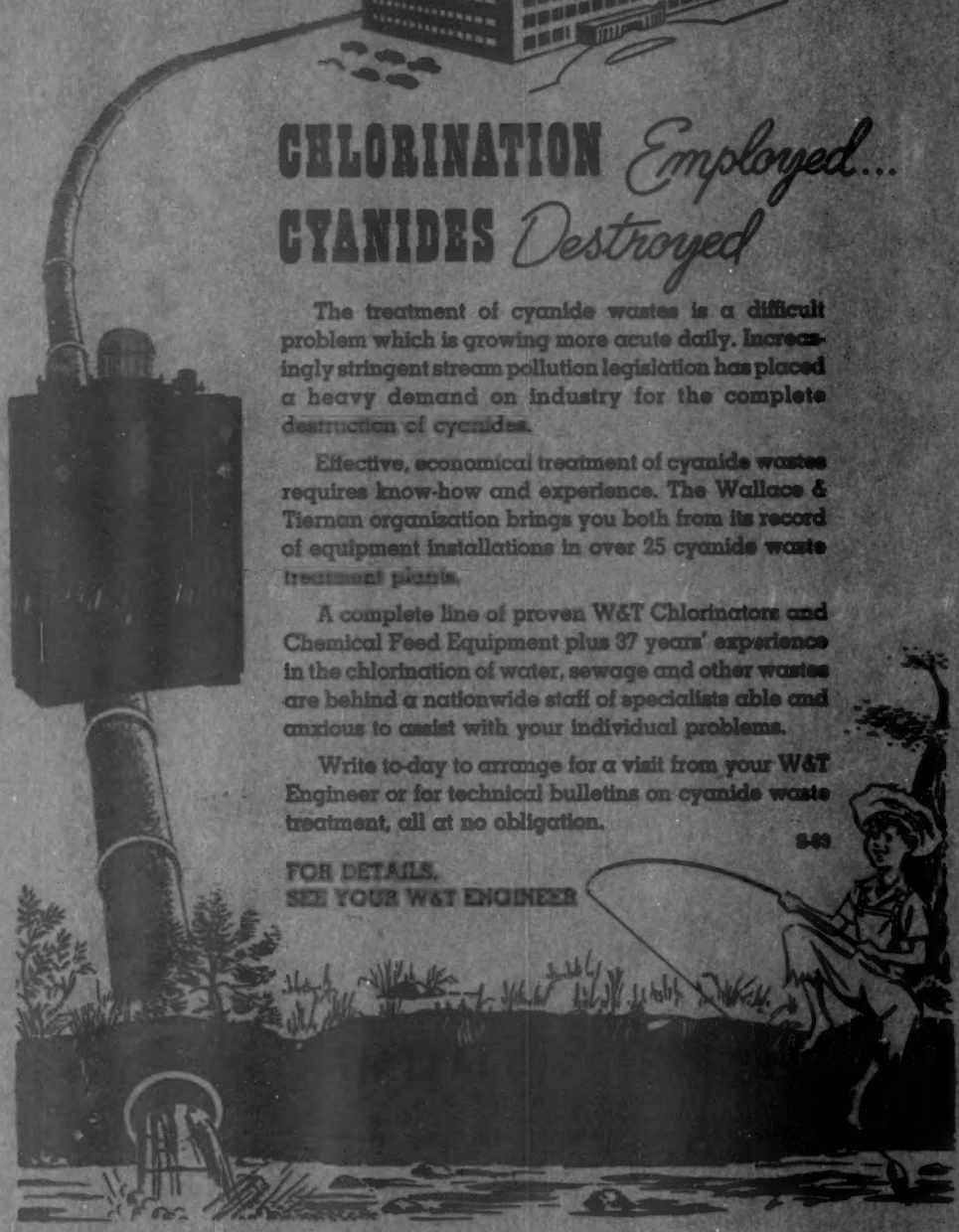
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